

EXPERIMENTAL FACILITY FOR E-BEAM IRRADIATION TEST OF PROTOTYPE IF TARGET IN RISF

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Abstract

Nowadays project RISF is developed in IBS, Daejeon. One of the main project device is graphite target system for production of rare isotopes by means of the in-flight fragmentation (IF) technique. The power inside the target system deposited by the primary beam with energy of 200 MeV/u is estimated to be around 100 kW. The target represents rotating multi-slice graphite disc cooled by thermal radiation. Necessary step of the target development is integrated test of target prototype under high power electron beam modelling real energy deposit into target. This test is planned to be held in BINP, Novosibirsk, with the use of ELV-6 accelerator.

This paper presents the design of experimental facility as well as experimental program of test. Specifications of electron beam (energy close to 800 keV, size ~ 1 mm, total power 30-40 kW) are discussed. Parameters and design of basic devices and systems of facility are described.

INTRODUCTION

At the present time in IBS (Institute of Basic Science, Daejeon, Korea) the RISF (Rare Isotope Science Project) is carried out [1,2]. Project purposes are production and investigation of new isotopes of chemical elements for fundamental research. In RISF, in particular, the In Flight (IF) fragmentation method of isotope production, wherein the heavy-ion beam energy is up to 200 MeV/u and diameter is ~ 1 mm cracks on the solid-state target (stripper), is realized [3]. IF target represented the rotating multi-layer thin graphite disk in vacuum with cooling by its own thermal radiation [4]. Its peculiarity is high working temperature (up to 1900 °C) and temperature gradient.

Presented paper describes planned testing of multi-layer target prototype under the high-power in vacuum.

EXPERIMENTAL PROGRAM

Goal of prototype testing is experimental check of general parts of IF target under conditions as close as possible to the operational ones. Test of prototype is envisaged to clarify a series of technical and physical problems which arise designing the target, including:

- to clear up the possibility of multi-layer target construction to dissipate the beam power, its resistance to thermal and mechanical stress;
- to test the cooling panels aimed to accept and remove the heat power, heat transfer balance;

- to check up the calculations of prototype operation conditions, in particular, the temperature fields of front and rear target layers;
- to test the control, measurement and protection methods proposed for the target subsystems design.

Heavy-ion beam will be modelled by the e^- beam of ELV-6 accelerator [5-6] with diameter down to ~ 1 mm, energy 800 keV (minimum possible) and power up to 40 kW. Maximum beam power will be limited by the graphite beam dump ability to utilize the e^- beam energy deposit [7].

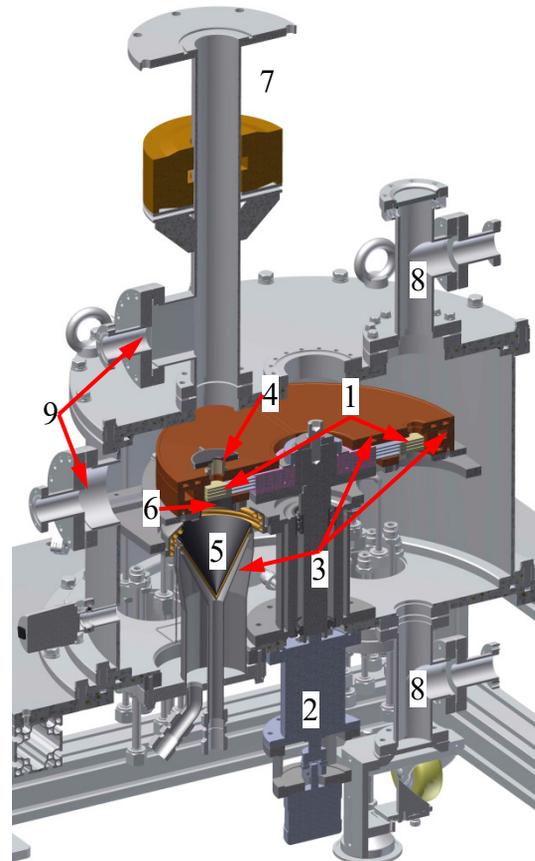


Figure 1: Experimental device. 1 – rotating target, 2 – rotary motion unit, 3 – cooling panels, 4 – protective diaphragm, 5 – graphite cone beam dump, 6 – protective graphite blanket, 7 – telescopic connecting tube to accelerator with beam control magnetic elements, 8 – optical ports, 9 – beam measurement plate ports.

PROTOTYPE DESIGN

Design of target prototype is presented in Fig. 1. Prototype represents rotating multi-slice graphite wheel (see Fig. 2) with 4 (optionally 3) layers [4] with diameter under beam 33 cm. Thickness of slice is 0.2 mm, distance between layers is 5 mm and diameter of disk is 350 mm (diameter under electron beam is 250 mm). Each layer of target is designed for beam power deposit up to 4÷10 kW. Target is covered by the water cooled copper panels. Target is mounted on the shaft with vacuum dry bearings and driven by an external electromotor via the vacuum rotary motion feedthrough. Special graphite protective diaphragm is placed before target. Conical high-temperature graphite beam dump [7] is placed after target. The prototype is housed in a water cooled, stainless steel vacuum chamber.

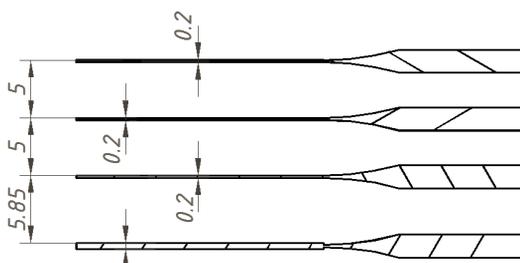


Figure 2: Layout of rotating target.

Vacuum Chamber

The vacuum chamber consists of a cylindrical volume made of stainless steel 316. Walls of chamber are equipped with cooling channels. Chamber also has the optical ports (for optical measurements of target temperature fields), electric ports (for measurement and control of different parameters) and separate pumping port. Also installation includes telescopic tube connecting the chamber and ELV-6 accelerator with the system of beam control/measurement.

Graphite Beam Dump and Protective Blanket

Beam dump with thickness 2 mm is detailed described in [7]. It is aimed to utilize the electrons passed through the target because of rotating target total thickness is not enough for full stopping the 800 keV electrons. Beam dump is insulated from installation body. The signal of current from beam dump is used for interlock unit.

Also special graphite blanket (covering outlet hole in rear cooling panel) is integral part of beam dump.

Protective Diaphragm

The protecting diaphragm is installed in order to protect the vacuum chamber and other metal parts of the construction from the e-beam hit. The diaphragm comprises (see Fig. 1) the graphite washer with 4 mm thickness, 14 mm internal diameter, and 70 mm external diameter. The washer is located right before the cooling channels and prevents the beam hit anywhere but to the prototype converter. The diaphragm is insulated from the

rest part of the prototype and has the current outlet. The signal from this outlet enters the interlock unit which is described below.

Cooling Panels

Cooling panels are used to remove the excess of heat from prototype operating zone. Panels are made of copper and sectioned on top and bottom target, top and bottom beam dump panels. Thermal flow removed by the each panel can be measured. Each panel includes the covering lid and the panel body with water channels. The body and the lid are welded together. In order to provide better heat removal from the graphite plates, the panel surfaces are blackened following a custom technology.

Main Measured Parameters

- Temperature distribution over the front and rear surfaces of rotated target. Measurements are performed using the special Thermal Imaging IR Cameras, Flir (SC660) [8] and Chino (IR-CAQ2CS) [9] through the optical ports made from radiation resistant glass (see Fig. 1). Camera placed separately from vacuum chamber in the local radiation protected area. Target image transfers to camera by the optical line made from the mirrors.
- Temperature at the crucial places of the prototype body – cooling panels, target shaft, diaphragm support etc. Measurements are performed using the thermocouples.
- Measurement of heat flow from cooling panels – by the calorimeters (water flowmeters and temperature differences).
- Beam current deposit into protective diaphragm and beam dump.
- Electron beam position and current distribution.
- Measurements of the rotation speed and motor power are carried out by the motor controller.
- Measurements of beam total current and energy are performed by ELV-6 control system.

ELECTRON BEAM CONTROL/MEASUREMENT

For beam size and position the simplest magnetic system is chosen (see Fig. 3). It consists of 3 existing units: coaxial magnetic lens and 2 pairs of correctors. Lens has 80 mm, magnetic field on the lens axis can reach 0.13 T. This lens is enough for focusing the electron beam down to 1 mm on the target. Correctors have enough low inductance to be used not only for beam position control, but for beam size measurement in the scanning mode condition (see Fig. 4).

Measurements of beam position and power distribution performed using the 2 plates with thickness ~ 2 mm (not less than full stopping length). First plate has array of diagnostic holes like pepper pot. The both plates are grounded via the shunt resistor. Electron beam is linearly scanned along plates by the magnetic correctors. In this case current signal from the second plate gives us information about beam current distribution.

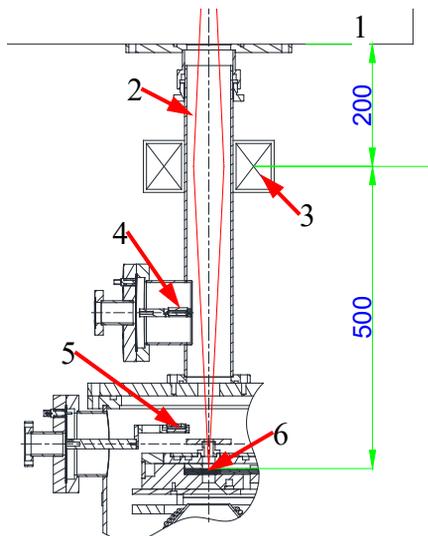


Figure 3: Magnetic system layout. 1 – ELV-6 accelerator, 2 – telescopic connecting tube to accelerator, 3 – magnetic elements, 4 – holes plate, 5 – current measuring plate, 6 – rotating target.

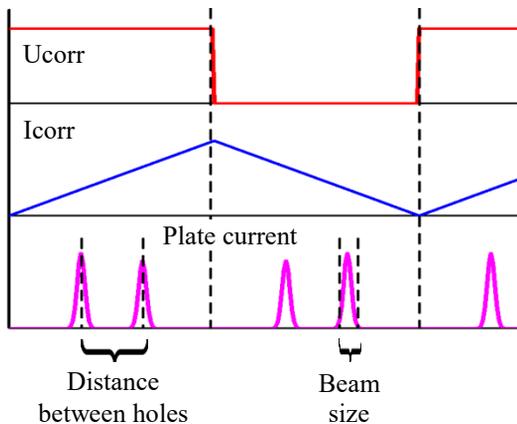


Figure 4: Time diagram of correctors parameters and measuring plate signal.

ENGINEERING AND LOCATION

Engineering includes separate control room and experimental hall with:

- biological shielding
- electrical supply 100 kW
- technical distillate up to 5 m³/h
- ventilation system with up to 5 exchange ratio
- racks with electronics
- optical line from vacuum chamber to IR camera

Experimental equipment is located in 3 separated areas (Fig. 5):

- Vacuum chamber with internal devices, water flow meters, temperature detectors are placed directly under electron beam in the bottom floor of ELV-6 experimental hall;
- Most part of digital registration devices in cRIO-9066 format, IR camera, analogue interlock/ matching

unit are placed in the top floor of ELV-6 experimental hall inside the local radiation protected area;

- Control desk and auxiliary devices are placed in ELV-6 control room.

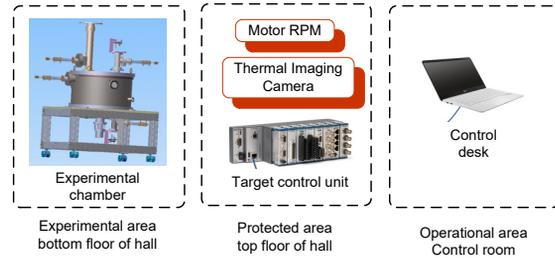


Figure 5: Experimental equipment location.

CONCLUSION, TIME SCHEDULE

By now all principal scientific and technical decisions are accepted, experimental installation is designed. Most part of equipment and devices is fabricated or purchased.

Final production and cold test of prototype is planned before end of 2016, experimental program under electron beam will be performed in BINP during march-april of 2017.

REFERENCES

- [1] <http://risp.ibs.re.kr/>
- [2] Y. K. Kwon et al., Status of Rare Isotope Science Project in Korea, *Few-Body Syst* (2013) 54:961–966.
- [3] K. Tshoo et al., Experimental systems overview of the Rare Isotope Science Project in Korea, *Nuclear Instruments and Methods in Physics Research B* 317 (2013) 242–247.
- [4] S.G. Hong et al., Design and test of a graphite target system for in-flight fragment separator, *Nuclear Instruments and Methods in Physics Research A* 752 (2014) 1–5.
- [5] R.A. Salimov et. al., DC High Power Electron Accelerators of ELV-series: Status, Development, Applications, *Radiation Physics and Chemistry*, 2000, Vol.57, Iss. 3-6, pp. 661-665.
- [6] Yu.I. Golubenko et al., “ELECTRON ACCELERATOR OF ELV-TYPE AND THEIR WORLDWIDE APPLICATION”, *Proc of APAC* 2007.
- [7] K.V. Gubin et al., “High-power high-temperature graphite beam dump for e-beam irradiation test of prototype IF target in RISP”, *Proc. of this conf.*
- [8] FLIR systems Inc., SC660 www.flir.com
- [9] CHINO Co., IR-CAQ2CS www.chino.co.jp