HIGH-POWER HIGH-TEMPERATURE GRAPHITE BEAM DUMP FOR E-BEAM IRRADIATION TEST OF PROTOTYPE IF TARGET IN RISP

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Abstract

Nowadays project RISP is developed in IBS, Daejeon [1,2]. One of the main project device is graphite target system meant 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 [3]. The target represents rotating multi-slice graphite disc cooled by thermal radiation [4]. Necessary step of 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 [5-7]. Heavy-ion beam will be modelled by the e^- beam of ELV-6 accelerator with diameter down to ~1 mm and energy 800 keV (minimum possible).

IF target is not full stopping target for an electron beam with energy 800 keV. Considerable part of beam energy will be not absorbed by a target material and must be deposited into special beam dump. In this paper the design of beam dump of the graphite cone geometry cooled by thermal irradiation is described.

BEAM DUMP PURPOSE AND LAYOUT

Beam dump is mainly purposed for utilization of electrons passed through the rotating target and removing the excess energy from experimental area. Beam dump is insulated from installation body. Simultaneously it means prevention the direct passing of high-energy electrons into metal surfaces. Moreover, it is specified using of current signal from beam dump for fast interlock unit. These tasks cause general layout of beam dump devise is shown in Fig. 1.

- Graphite conical beam dump with thickness 2 mm absorbs most part passed electrons and removes its energy by the thermal irradiation. The thickness of graphite is enough for electron beam full stopping.
- Cylindrical graphite blanket protects the outlet metal devices from electrons scattered with high angles. This device also is cooled by thermal irradiation.
- Water beam dump and additive cooling panel removes heat by water cooling channels. Also this devices saves overheat of the different parts of installation against of direct graphite thermal irradiation.
- Ceramic insulator gives possibility to measure electron beam current through graphite cone.

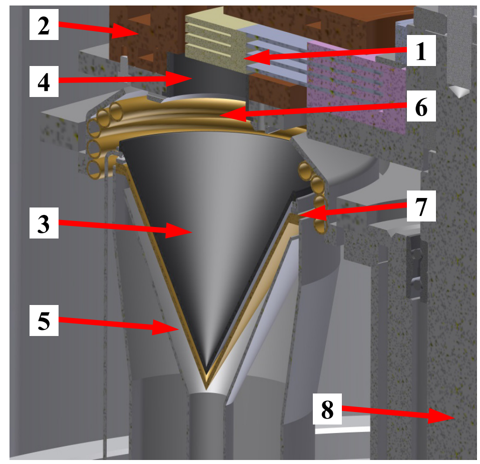

Figure 1: Layout of beam dump: 1 – multi-slice rotating target, 2 – cooling panel, 3- graphite cone beam dump, 4 – graphite blanket, 5 – water beam dump, additive cooling panel, 7 – ceramic insulator, 8 – target shaft.

Main problem of beam dump development is optimization of device size and placement. First of all, beam dump must have enough large size for providing high flow of thermal irradiation without overheat of graphite more than 1900-2000 °C. In other hand, a beam dump size is limited by maximum sizes of installation: distance between target shaft and electron beam axis is ~ 10 cm. Also, operational conditions of beam dump will determine maximum possible electron beam power during experiment

Principal subtasks of target development are next:

- simulation of electron beam scattering and passing through rotated target,
- estimation of beam dump heating, temperature and thermal stress distribution, ultimate parameters of electron beam,
- estimation of heat removal by external cooling channel,
- optimization of beam dump design and operational conditions,
- definition of ultimate experimental regime for the next prototype test [4, 7].

SIMULATION OF ELECTRON BEAM SCATTERING

Simulation of electron beam passing through the rotating target was performed by G4beamline code based on GEANT4 by means of Monte Carlo method. Main

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ISBN 978-3-95450-181-6

parameters of simulation were:

- Thin graphite target. 3 layers with thickness 0.2 mm, diameter is 20 mm, distance between layers is 2 mm, graphite density is 1.85 g/cm^3.
- Beam dump axis is normal to target, thickness of wall was 2 mm, graphite density is 1.85 g/cm^3.
- Electron beam is normal to target (along to the beam dump axis), zero transverse size, monoenergetic, with kinetic energy 800 keV was taken.

Computed energy-radial and energy-angular distributions of electrons passed through the target are presented in Fig. 2. Number of back scattered electrons is negligibly small. Results of simulation follow next conclusions:

- Passed beam has enough small size (greatly less than typical size of beam dump devices). Electron beam after passing through a target can be considered as a point size beam for a next beam dump optimization.
- For following step of modelling only one dimension angular distribution of passed beam power density was used.

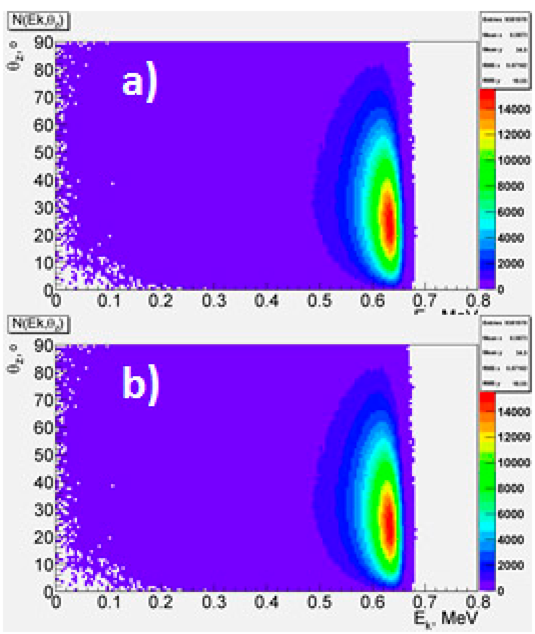

Figure 2: Energy-radial (a) and energy-angular (b) distribution of electrons at outlet of rotating target.

OPTIMIZATION OF BEAM DUMP GEOMETRY

Applying a simple graphite disk shape as a beam dump is not suitable, because the square of surface is not enough to absorb significant power flux of electron beam. Due to this reason and reducing transverse size of a beam dump unit as smaller as possible the conical shape with thin wall was taken for a beam dump particular design. Angular electrons distribution defines a minimum transverse size of cone base and a distance between graphite target and a cone. Also it is strongly important to make a correct shielding all other vacuum chamber elements against of electron flux.

The cone height was varied to have a moderate value of energy deposition in beam dump wall. Otherwise, the temperature of wall should be extremely high. It is well known, graphite can operate long time with temperature about 1900-2000 °C and short time (several tens hours) with a temperature up to 2100-2150 °C. In case, a temperature is higher graphite material degradation and evaporation came too fast. Due to maximum temperature we estimate the ultimate heating power density and temperature distribution in graphite cone and blanket.

Procedure of optimization consists of temperature distributions for varied parameters (cone diameter and heights, blanket diameter and length, distance between cone and target) and definition of minimum acceptable overall dimensions with a maximum acceptable electron beam power.

As a result, optimal geometry of cone beam dump and blanket is shown in Fig. 3. Temperature and heating power distributions for these parameters are presented in Fig. 4-5. Due to very small thickness of graphite, temperature difference through wall depth is negligible small as well as thermal flux along graphite surfaces.

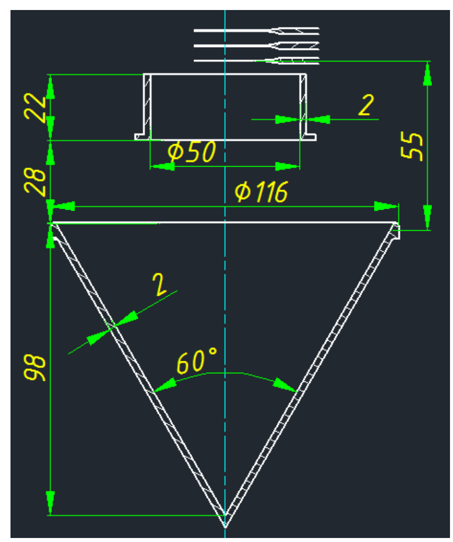

Figure 3: Geometry of graphite beam dump recommended for fabrication.

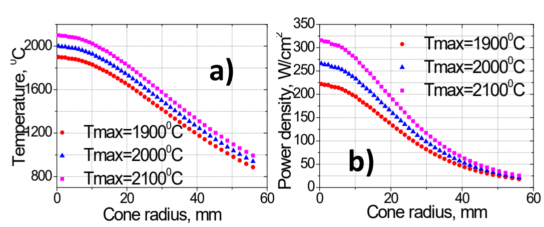

Figure 4: Temperature (a) and accepted heating power (b) distributions over cone for geometry Fig. 3.

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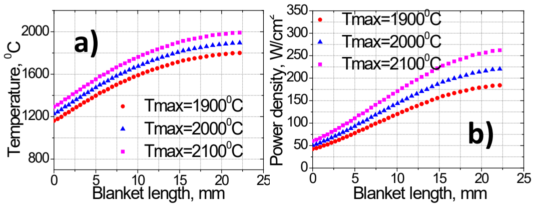

Figure 5: Temperature (a) and accepted heating power (b) distributions over blanket for geometry Fig. 3.

In addition, energy deposit into different graphite parts of prototype for optimal beam dump geometry via different maximum temperature was calculated. Results are presented in Table 1.

Table 1: Energy deposit into different graphite parts of prototype for different maximum acceptable temperature.

Maximum temperature		1900^{0}C	2000^{0}C	2100^{0}C
Total beam power, kW	100%	27.3	32.6	38.8
Energy deposit in 1st layer, kW	8.4%	2.29	2.74	3.26
Energy deposit in 2nd layer, kW	10.6%	2.90	3.46	4.11
Energy deposit in 3rd layer, kW	16.1%	4.40	5.26	6.25
Energy deposit in blanket, kW	16.2%	4.42	5.29	6.29
Energy deposit in cone, kW	48.7%	13.3	15.9	18.9

CONCLUSION

As it is shown, maximum reachable energy deposit in single layer consist about 3÷6 kW, on the contrary, nominal energy deposit in single layer of real IF target must be in range 4÷10 kW [4]. But we cannot increase size of beam dump. It means for achievement of higher energy deposit we must use additive layer purposed to absorb additive beam energy. Of course this variant does not abolish principal scientific and technical decisions for beam dump.

By now, experimental testing of IF prototype planned at spring of 2017 in BINP, experimental installation is designed. Most part of equipment and devices is fabricated or purchased.

Experiments with 3 layers as well as 4 layers are discussed. In first case main goal is accurate checkup of device in principal include correspondence between simulations and real working conditions. In second case we can test of different units at conditions most closed to planned conditions of IF target.

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ISBN 978-3-95450-181-6