Development of High Power Targetry Systems at FRIB

Jian Gao, Wolfgang Mittig and Jie Wei
Facility for Rare Isotope Beams, Michigan State University, MI USA 48824
Email: gaoj@frib.msu.edu

The Target and Beam-dump Systems Group (TBSG) of Facility for Rare Isotope Beams (FRIB) at Michigan State University (MSU) is interested in participating in the activities promoted by the Accelerator Frontier subgroup "Target/Sources" of the Snowmass 2021. TBSG's primary mission is to develop, construct, and operate high power targetry system of the FRIB project [1], where heavy ions up to Uranium are accelerated to energies above 200 MeV/u and focused to 1 mm spot size striking the target at 400 kW average beam power. Here we summarize the ongoing R&D programs and the future opportunities related to High Power Targetry (HPT).

Target System

To achieve required high resolution of the fragment separator, the beam spot on the production target needs to be on the order of 1 mm size. Due to the very specific high energy loss of heavy ions, the extreme high power density makes the static solid targets no longer feasible. Considering 400 kW beam power at FRIB, the TBSG is developing multi-slice graphite rotation system to reach power densities of up to 60 MW/cm^3 [2]. With rotation speed up to 5000 RPM and high beam intensity, the bearing used in the system needs to be vacuum compatible, high radiation resistant and the lubricant needs to have high temperature tolerance. An induction heating system is being developed in the TBSG to investigate bearings made of various materials and temperature tolerance and radiation resistance of different vacuum compatible lubricants. The TBSG is working with industrial providers on the design of 3D printed targetry bearings made of the new filament materials.

Beam Dump System

Downstream of the production target, over 300 kW remaining primary beam power needs to be absorbed in the beam dump. A rotating water cooled thin wall shell drum was selected as the basic concept for the beam dump system at FRIB [3]. Ti-6Al-4V was proposed as a candidate material mainly due to its enhanced mechanical properties and radiation and corrosion resistance.

Since the rotating beam dump system is installed in the vacuum vessel, the radiation resistant sealing on the interface between high pressure water and high vacuum is required. TBSG is developing a seal design via using Ferrofluid Feedthrough/ Garlock seal as an intermediate seal that can be tested offline. Due to the complex flow field inside the rotating drum, charactering the surface heat transfer coefficient is a major challenge, especially with the high gas production of up to 1 atm L/s due to radiolysis of water. R&D program of beam dump using computational fluid dynamics modeling can contribute to a better understanding of its performance and future design optimization. Previous study of the irradiation damage in Ti alloy was mainly performed using neutrons and protons for nuclear industry applications. Investigating the swift heavy ion damage in Ti alloys would be of interest for high intensity heavy ion beam accelerators [4]. The TBSG is also pursuing the thin Ti alloy shell with 0.5 mm thickness via 3D printing, presently at the limits of the technology due to the large size of 70 cm diameter.

The above R&D program we developed at FRIB will be beneficial for the future development of High Power Targetry. An active collaboration with the Accelerator Frontier of the Snowmass 2021 can certainly boost our research program. The newly developed systems and technologies will not only benefit the large HPT community, but also advance the technology and education. These developments are key for the present and future very high intensity accelerators.

References

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