Simulation to design the target cooling arrangement for high current Nuclear Astrophysics experiments

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1. Introduction

To perform nuclear astrophysics(NA) experiments in laboratory, a high current ion-beam is required due to its low fusion or capture cross-section. Now high current beam will generate a huge amount of heat inside the target. Such high temperature can cause melting of target. So a cooling arrangement is required to perform such high current experiment without melting issues. Now heat generated inside a thin target (much less than projectile range) is much less compared to thick targets (greater than projectile range) . And for that reason melting is not such a big issue for thin targets. A detailed simulation has been done in T. Bar et al. [1] where it was assumed that temperature of the cooling surfaces were at fixed temperature (4^0C). In reality cooling of target can be done by designing a proper cooling frame. Inside that a coolant (here chilled water) will flow and target will be attached by that frame. Here simulation has been done to have an idea about the proper cooling frame design and flow rate of water to maintain temperature of the target under melting temperature. For targets like carbon, have more melting issues due to its low thermal conductivity. For that reason here in this simulation a $^{12}C(^{12}C, x)$ reaction is considered. All calculations has been done in simulation package software ANSYS and spacecalim is used to design the simulation geometry.

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2. ANSYS software

ANSYS is a numerical software package which can calculate heat transfer through conduction, convection and radiation simultaneously . In this calculation ANSYS FLUENT solver is used. It digitise the simulation geometry and then solve it numerically.

3. Boundary condition and cooling processes

Here a 20mm × 20mm cross-sectional graphite target is used with thickness 1 mm. Inlet water and ambient temperatures are taken at 12^0C(285.15K) and 20^0C(293.15K) respectively. A continuous $^{12}C^{2+}$ beam is considered with a beam spot of diameter 6 mm. First heat generated in beam spot is transferred to tantalum frame placed behind the target through conduction then that heat is transferred to the flowing chilled water inside the tantalum frame. Water takes all the heat by convection process. All open surfaces are considered to perform radiation loss with the ambient. Since all these set-ups will be in the vacuum so there is no point of heat loss to the surrounding atmosphere by convection.

4. Results from simulation

Simualtion has been done for $^{12}C(^{12}C, x)$ reaction. A 1 mm ($\sim 225.3 mg/cm^2$) thick *graphite* target is used. Beam energy is around (4.2-9.5 MeV) [3]. Here for simulation purpose beam current is taken to be $250\mu A$. Range and stopping power in C at that energy are respectively 3.43 μm and 7.346 MeV/(mg/cm^2)(calculated from SRIM)[2]). Charge state of carbon beam is 2+. FIG.1 shows the cooling frame used for simulation

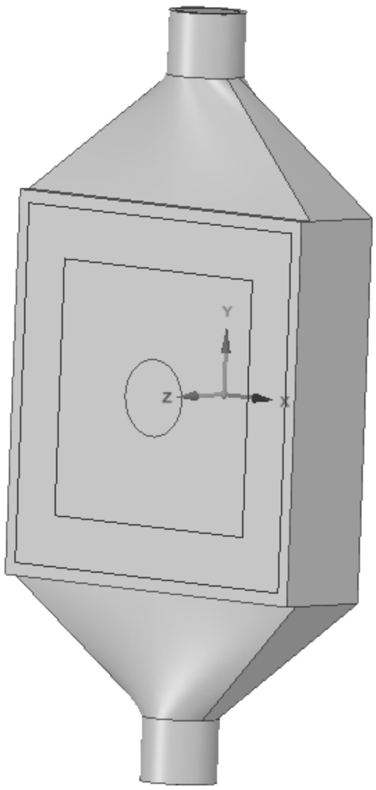

FIG. 1: Target placed with cooling frame.

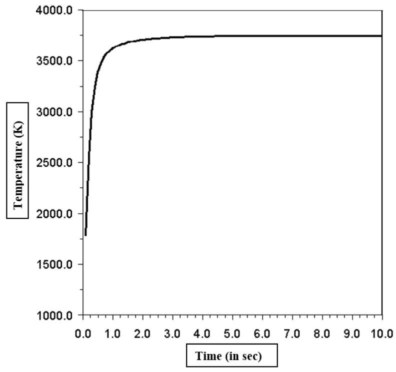

FIG. 2: Temporal variation of temperature without any cooling arrangement.

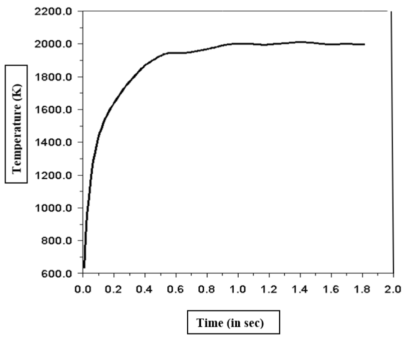

FIG. 3: Temporal variation of temperature with cooling arrangement.

in this study. FIG. 2 shows temporal variation of temperature of graphite target in absence of any cooling system. In absence of any cooling system heat dissipation happens only through radiation. FIG.3 shows temperature profile of that target in presence of cooling arrangement.

5. Discussions

From above results it is clear that applying cooling arrangement can decrease the temperature significantly. Purpose of this work is to find a proper cooling frame design with suitable flow rate such that temperature can be maintained far below the melting temperature. Apart from melting, high temperature can cause other effects on targets such as crystal defect, sputtering etc. So maintaining temperature well below melting is always desirable, specially in case of high current nuclear astrophysics experiments.

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References

[1] T.Bar et al., *Nuclear Inst. and Methods in Physics Research B* 449(2019) 105–11

[2] Ziegler, J.F., 2013. SRIM-2013 software package. see http://www. srim.

[3] T. Spillane et al.*PRL 98, 122501 (2007)*