to the top in Fig. 1. The decrease of neutron flux from location 4 to location 7 is due to the increasing distance between the target and the detector, while the steep decrease of neutron flux from location 5 to location 1 is due to both the neutron absorption of target and the increasing distance from the target to the detector. It is noteworthy to mention that the difference of neutron flux between the central location, *i.e.* location 4, and the lower location, *e.g.* location 1, attains more than two orders of magnitude for 250 MeV proton beam on lead or bismuth target. The neutron flux at the central location attains 2×10^{13} n/cm^2/s with the beam current of 10 mA. Given as the designed flux of 2×10^{14} n/cm^2/s for C-ADS facility, it should be very fast to attain the designed flux at the central location. On the other hand, it will take more time to attain the designed flux at the lower or upper locations which are far from the target.

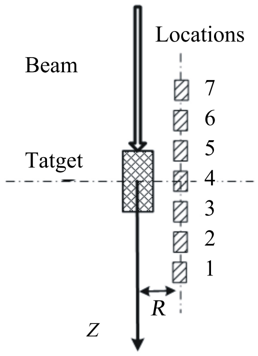

Fig. 1 Incore neutron flux monitoring techniques in an ADS facility where the spallation target located vertically at the centre of the core is bombarded vertically by a proton beam. The neutron flux is measured at seven locations from the top to the bottom.

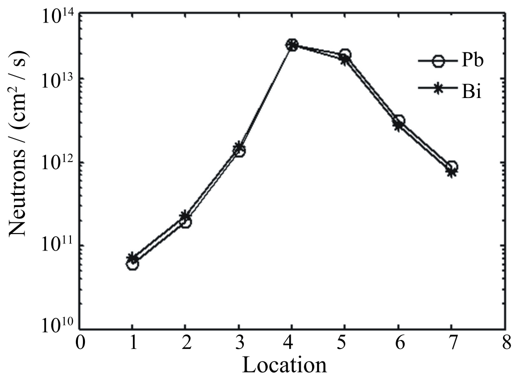

Fig. 2 Neutron flux spectrum of the spallation reactions for 250 MeV proton beam with the current of 10 mA impinging on lead and bismuth targets.

Finally, we propose incore monitoring technique for an ADS facility as follows. During the operation of the reactor, the incore neutron flux should be measured at multiple vertical locations. The detectors for the measurements of incore neutron flux may either be left in a fixed location or provided with a motorized drive to allow move vertically within the reactor core. During the reactor startup, as the neutrons from the spallation target dominate, the incore neutron detectors should be put at the central location which is close to the target for the commissioning measurements of the proton accelerator.

* Foundation item: Strategic Priority Research Program of Chinese Academy of Sciences (XDA03010000).

5 - 12 New Research on Accelerator Driven Subcritical System Spallation Target

Wang Huiqiao and Yang Lei

Nuclear power is a mature technology of clean energy, with the incomparable advantage of other energy sources to resolve conflicts in the fast-growing energy needs and environmental protection. A major issue of the development of nuclear energy facing is the spent fuel deposal, especially the safe disposal of long-lived high-level radioactive waste. At present, accelerator-driven subcritical system (ADS), composed of a high energy proton accelerator, a spallation target and a subcritical reactor, is recognized as the most promising nuclear waste transmutation technology for its excellent safety, powerful transmutation ability and good neutron economy. Therefore, ADS is the most promising tool transmuting large quantities of radioactive waste to reduce the risk of deep storage[1].

As one of the ADS subsystems, spallation target consists of the target body, the beam-target coupling system, the heat exchange system, drive system, *etc.* Its main function is to generate neutron through spallation reactions caused by high energy protons bombarding on heavy nuclei in the target for maintaining the subcritical fission reaction[2], so as to achieve the purpose of transmutation of nuclear waste. Meanwhile, the spallation reaction energy deposed in the system is transferred out to maintain the normal operation of the system.

By researching on domestic and foreign spallation target programs, to avoid high radiotoxicity temperatures-corrosion effects and other serious flaw of liquid metal targets, we proposed a new target concept: the gravity-driven dense granular flow target (DGT), which has the advantages of both the solid and liquid targets. DGT is designed with fluidized solid grains, which can effectively solve the problem of heat removal. As the target medium, the small diameter tungsten (grains) not only produce the neutron, but also transfer the heat deposed in the system by proton beam, and the removal capability is more than twice that of the usual liquid metals. Meanwhile, the dense granular flow can avoid instability of ordinary hydrodynamic fluid. Furthermore, theoretically fluidized solids target can bear more than a few dozen of MW beam power.

DGT uses tungsten grains as spallation material, leading to better neutron science characteristics while maintaining lower corrosive and product toxic. At the same time, because of the stability of granular flows, it has simpler design parameters. The program uses a redundant, fault-tolerant design: select mature industrial products, technology and relatively conservative operating parameters, maximize equipment life and reliable operation, and enhance security of accident conditions.

Preliminary calculations of this target show that the CIADS desired target with 2.5 MW beam power have an average temperature of less than 550 °C at the outlet, and 10 MW target system have an average temperature of less than 650 °C at the outlet. As soon as the DGT was put forth experts in this area made positive comments and showed great concerns: CERN neutron had beam experiments with a number of European laboratories; Belgium MYRRHA team had arranged staff and funding to carry out related designs. At present, the technical verification of DGT has already started.

References

[1] Shouxian Fang, Naiyan Wang, Duohui He, et al., Bulletin of Chinese Academy of Sciences, 24(2009)641.
[2] Wenlong Zhan, Hushan Xu. Bulletin of Chinese Academy of Sciences, 27(2012)375.

5 - 13 Thermohydraulics Experimental Research Progress of Spallation Target

Yang Weifeng, Zhang Xueying, Qiang Chengwen, Zhao Qiang, Wang Fei, Li Long and Xu Xiaowei

In order to verify the simulation results of the liquid metal target and the granular flow target, the spallation target laboratory have established several experimental benches and carried out some related experiments on these benches.

1. Liquid Target Research

A water loop has been established in 2012 for investigating the flow behaviors of water in windowless target and has been rebuilt in 2014 for experiments of window target. The experiments are conducted in an approximately 1:1 sized window target model shown in Fig. 1. The flow pattern inside the spallation area is visualized by means of the particle image velocimetry (PIV). The flow range of the present experiment is between 8.4 and 20 m^3/h, and several typical flow patterns are observed under the conditions of different inlets and outlets.

For researching behaviors of LBE (Lead-Bismuth Eutectic), LiMeTS (Liquid Metal Test Stand) was constructed by PSI (Paul Scherrer Institute) and has been handed over to IMP (Institute of Modern Physics) under a cooperation framework between PSI and IMP. LiMeTS has been transported at IMP in September 2014 and assembled in January 2015, which is shown in Fig. 2. LiMeTS was divided six independent parts in the transportation and combined together with the help of an integral platform. Then the electric lines and gas pipes are being connected in recent months. LiMeTS will play a vital role in the future research as a solid experimental basement.

Fig. 1 (color online) Window target model in the water loop.

Fig. 2 (color online) The photo of LiMeTS.

Fig. 3 (color online) The photo of STELA.