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Status of CANS at home and abroad and Introduction to New On-site Neutron Source Development Project with 30 MeV Cyclotron for neutron radiography

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1. Introduction

According to the advance of accelerator technologies, various facilities and application with accelerator-based compact neutron sources (CANS) are actively developing in the world and even in domestic neutron field considering the decrease of the existing neutron source such as research reactor.

In the present study, activities for CANS at home and abroad are summarized, and newly started domestic research project for cyclotron based neutron source development for neutron radiography is introduced.

2. Status of CANS development at home and abroad

Recently, with the advance of accelerator technology, the EU, Japan, and the United States have ensured the continuity of neutron research using CANS, and are actively promoting various research on industrial applications, as well as medical utilization through BNCT investment.

- ✓ The EU, mainly in France and Germany, is trying to secure the continuity of neutron research in preparation for decommissioning of research reactors by building accelerator-based neutron resource.
- ✓ Japan is conducting neutron imaging research using small accelerators, prior study on J-PARC, and industrial utilization.
- ✓ The United States, focusing on industries, has been promoting production of military neutron imaging and medical isotopes, after the successful industrialization of high-dose fusion neutral resources.

These activities are shared and cooperated in the Union of CANS and several IAEA non-spallation neutron source meetings.

In Korea, neutron research and application has been performed with the research reactor HANARO at Korea Atomic Energy Research Institute (KAERI) from 2005, whose construction started in 1995. HANARO has been successfully used for Neutron scattering and science, radiography, medical isotope production, material irradiation test, and so on until its temporary shutdown in 2014. Recently, due to increased industrial demand, neutron production based on linac (KOMAC) for soft error test has begun.

In order to continue neutron research with the restart of HANARO and increasing demand in the industrial, defense and medical sectors, Korea CANS (KCANS) was established to share information and encourage collaboration by holding several meetings since 2016. Currently, about 50 members are showing their interest in neutron research, its application and neutron source development.

Recently, several project proposals for new neutron source development with the existing accelerators, industrial application with DD neutron source, and broadening application from the developed neutron application with HANARO have been submitted or prepared to the government;

(1) From this year, 30 MeV cyclotron based neutron source and on-site neutron radiography development was started at KAERI. The main objectives are to develop the TMRS for 30 MeV cyclotron, to produce over 10^{12} n/s of neutron yield, and to provide users' service for radiography.

(2) Upgrade project of current 100 MeV linac of KOMAC to 200 MeV is being prepared for the application of soft error, which contains proton itself irradiation and high energy neutron irradiation with several target rooms.

(3) On-site neutron application with the new neutron sources such as DD source, cyclotron based one, and linac based one for nuclear fuel examination system development, instead of Cf-252, industrial and medical isotope production, radiography, and so on.

Also, the proton accelerator based BNCT (A-BNCT) facility is under development in Korea for commercialization and a new cancer treatment technology, in which Neutron beams for treatment are produced from a beryllium (Be) target and an 8 mA, 10 MeV proton beam.

As in other countries, while neutrons are not sufficient due to enhanced safety, efforts are being made including industrialization as a means to revitalize them and securing alternative neutron resources, in order to bring about multi-faceted investments.

3. Introduction to New On-site Neutron Source Development Project with 30 MeV Cyclotron for neutron radiography

Due to the neutron characteristics of its reaction with low atomic material, it has been used for such as an explosive, an ammunition, an aeroplane etc., especially where X-ray imaging has limitation. So far, research reactor, HANARO has provided the radiography (~10^{14} n/cm^2·s, 10^{18} n/s), but the accessibility becomes decreasing due to the recent strengthened regulation and the limitation of the specimen size. And the needs of on-site neutron source for radiography of industry and defense are increasing.

A new project was started at April 2020 to develop the neutron production up to 10^{12} n/s considering the minimum neutron yield for radiography. The overall project scheme and concept of neutron source and radiography were introduced in Fig. 1. And it consists of the following Tasks;

(Task 1) Target-Moderator-Reflector-Shield (TMRS) system development.

(Task 2) on-site neutron radiography development and supply of stable proton beam. The well-established thermal neutron imaging technique will be used and compared with HANARO.

(Task 3) Comparison developed neutron radiography with X-ray ones with a company, in which more complex internal structure and feasibility/adavantage of neutron image will be confirmed.

(Task 4) For produced neutron energy and spectrum, and neutron flux will be measured at various location in the laboratory including the specimen.

Currently, Be target is selected as a target and other MRS design has been performed. Generally, Be targets are used at various neutron sources of proton accelerators since it is easy to manufacture and handling the Be target. A Be target with a thickness of few mm is used as a target for protons above about 20 MeV and it works as a structure material of the target system. The protons sink in a water-cooling channel behind Be and blistering in Be is much reduced. In case of low proton energy, thinner Be is used as a target and a three-layered structure is adopted to avoid the blistering, namely, Be, anti-blistering material and Cu cooling part.

4. Summary and future works

According to the advance of accelerator technologies, various facilities and application with CANS are actively developing at home and abroad. UCANS and KCANS are actively cooperating and promoting the facilities and applications. Recently, new cyclotron based neutron source development was started and it heads to apply into the neutron radiography in on-site of its application field. Through the success of on-site neutron production and radiography, the wider application of neutron in defence and industrial field are expected.

Furthermore, the application of the neutron can be generally divided according to its yield and also, the source should be prepared by each application differently from the very fluent source like research reactor. The development plan of KAERI is shown in Fig. 2 and DD neutron generators are being developed for applying into industrial isotope production and for replacing the Cf-252 in fuel examining system.

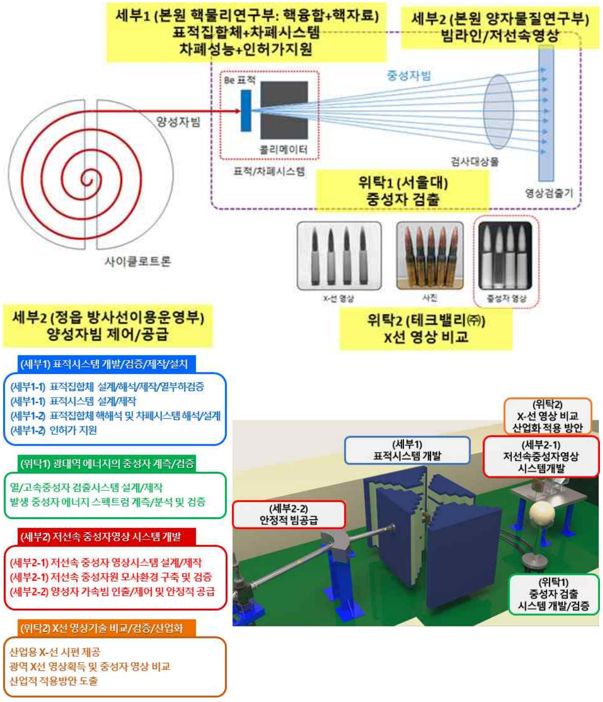

Fig. 1. Neutron application according to the neutron yields

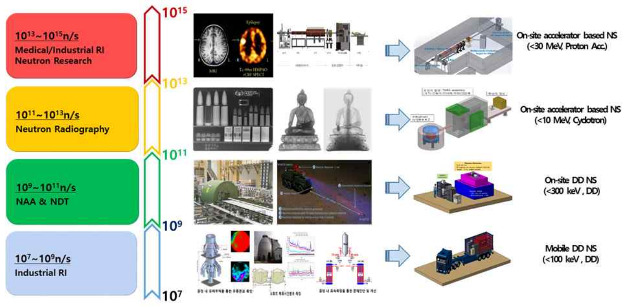

Fig. 2. Neutron application according to the neutron yields

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