ISBN: 978-3-95450-168-7 doi:10.18429/JACoW-IPAC2015-WEPWA019

DEVELOPMENT OF ACCELERATOR-DRIVEN COMPACT NEUTRON SOURCES

K. Hirota*, G. Ichikawa, M. Kitaguchi, Y. Kiyanagi, H. M. Shimizu,
K. Tsuchida, A. Uritani, K. Watanabe and JCANS Collaboration,
Nagoya University, Nagoya, 464-8602, Japan

Abstract

Compact neutron sources are good tools for neutron scientist. In this paper we will present the current situation of compact accelerator-driven neutron source and the status of the facility of Nagoya University.

INTRODUCTION

Neutron is a very good probe to investigate inner structure of materials. The large neutron facilities like J-PARC MLF and SNS were constructed in decade, and ESS facility are start to construct. These large facilities are very good tools to study in academic field. However, the opportunity to use is very low, many neutron scientists use this facilities once or several a year. The beam time is less than 10 days in many case science many scientists want to use these powerful machine. The scientists require more neutron beam to study physics, chemistry and engineering.

One of the solution to solve this situation is constructing Compact Accelerator-driven Neutron Source(CANS). The CANS has some merit comparing with large neutron facilities. The constructing cost is lower than larger facilities. The opportunity to use neutron beam is so frequently. All devices from accelerator to detectors are able to handle by ourselves, that is very good for student education. The amount of radiation is smaller than that of the large-scale facilities. Unfortunately the emitted total neutron is much lower than large facilities and it is not suitable for the measurement of statistics-dominant. We can use these CANS for BNCT(Boron Neutron Capture therapy), neutron imaging, device development and so on. In this paper we will present the current situation of CANS and the status of the facility of Nagoya University.

NEUTRON GENERATION

There are some methods for generating neutrons. In general, the emitted neutron flux has following relation,

$$NeutronFlux = I_{beam} \times Eff_n \times Eff_{Mod} \quad (1)$$
$$I_{beam} = I_{peak} \times (Duty) \quad (2)$$

where, I_{beam} is an intensity of accelerated beam, Eff_n, and Eff_{Mod} are efficiency of neutron emission and moderation, I_{peak} is a peak current of accelerated beam, duty denotes duty cycle of accelerator.

Fission reaction is using at research reactor, and spallation reaction is using at large neutron facilities like J-PARC, SNS, and ISIS. These two methods have good neutron emission efficiency. Photonuclear reaction and low energy proton (or deuteron) reaction are using at compact neutron sources. The other neutron emission methods are fusion reaction and radioisotope. These two methods are lower neutron flux than the other methods in the laboratory use.

In CANS, neutron emission efficiency is not so high and neutron flux is lower than that of large facilities. In order to compensate the neutron flux, these reactions require the incident beam intensity. One solution is increase duty ratio by using cyclotron or electro static accelerator. However, it is not suitable for the case of pulse imaging method, which need neutron TOF(time of flight) information. In this case, we have to try to increase the peak current by using linear accelerator. In these way, we have to select the suitable acceleration beam properties.

The incident beam energy is also important for CANS. High incident beam energy increasing the accelerator and radiation shield size, and also increase the construction cost. On the other side, the low energy beam decrease the neutron emission efficiency. The relation between incident beam energy and neutron emission is written in elsewhere [1]. The selection of beam energy and target should be carried out carefully. In less than 2 MeV region, the deuteron beam is only useful for CANS. But the moderation efficiency in eq. (1) is not so good because of the emitted neutron average energy is more than one MeV. In 2 - 5MeV region, proton beam and Li target is suitable for CANS, however Li target is difficult to use, and second solution is Be target [2]. In more than 5 MeV region, Be target is suitable [3].

NUANS

Nagoya University Accelerator-driven Neutron Source (NUANS) is constructing at Nagoya, Japan. The aim of this neutron source is the evaluation test machine about Li target for BNCT. In general, the total neutron emission needs 10^{13} n/sec for BNCT use. We are planning to achieve this number by using high duty machine, DC beam accelerator. An electrostatic accelerator, dynamitron and an ECR ion source are using for the incident proton beam injector. The proton beam energy and DC beam current are 2.8 MeV and 15 mA, respectively. The accelerator is doing the final test at production factory and shipping within few month.

The Li target and epi-thermal moderator are also important components for neutron source. We select the emboss structured target [4] and MgF_2 neutron moderator for NUANS.

* hirota@phi.phys.nagoya-u.ac.jp

ISBN: 978-3-95450-168-7 doi:10.18429/JACoW-IPAC2015-WEPWA019

UCANS AND JCANS COLLABORATION

It is very attractive to use our own compact neutron source in our university or laboratory. It is hard, however, to make a compact neutron source, because we have to make many neutron devices in a small laboratory and need many knowledge about neutron optics, neutronics, radiation shielding and so on. To solve this situation, we collaborate the neutron scientists with same purpose in the world. The UCANS (Union for Compact Accelerator-driven Neutron Source) [5] was formed in 2009 to support the ongoing development of small accelerator based neutron sources around the world, and to promote the exchange of information on emerging science and novel applications relevant to long-pulsed and/or medium-flux neutron sources. And JCANS(Japan Collaboration on Accelerator-driven Neutron Sources) [6] was also formed in 2011.

CONCLUSION

Compact Accelerator-driven Neutron Source are developed recently. These CANS machine have a good potential to apply for neutron science. Proton beam and Be target machines are developed and begin to use neutron science. Li target machine is developing for lower energy CANS machine.

REFERENCES

[1] M.R.Hawkesworth, Atomic Energy Review **15, No.2** (1977) 169-220

[2] S. Tasaki et.al., Physics Procedia **60** (2014) 181-185

[3] D.V. Baxter, et al., Nucl. Instr. Meth. B, **241** (2005) 209

[4] U.S. patent WO201401704A1

[5] http://www.ucans.org

[6] http://phi.phys.nagoya-u.ac.jp/JCANS/