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Plan of Neutron Source for Blanket Functional Tests and Material Tests using IFMIF/EVEDA Prototype Accelerator

IFMIF/EVEDA原型加速器を利用したブランケット機能試験及び材料試験のための中性子源の計画

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A fusion relevant neutron source is strongly desired for blanket functional tests and material tests toward DEMO. The International Fusion Material Test Facility (IFMIF) is one of the most promising candidates of the fusion relevant neutron source. Here, a plan is presented for a new neuron source using an IFMIF/EVEDA prototype accelerator with 125 mA and 9 MeV D^+ beam and a lithium test loop for the IFMIF target facility. Expected performances of three options (9 MeV and upgrading to 26 or 40 MeV) are discussed. The option of 40 MeV is desirable, however, the option of 26 MeV is acceptable for blanket functional tests and material tests.

1. Introduction

For a fusion demonstration reactor (DEMO), development of blankets is one of the most important issues. Especially, tests of blanket functions and blanket materials under fusion relevant neutron irradiation are strongly desired. Of course, the ITER Test Blanket Module (TBM) [1] program is an important milestone to confirm the integrated performance of the blanket and also validation of the blanket materials. However, TBM experiment under long pulse DT operation will be expected 2030 or later, and the neutron fluence is not enough for the material tests.

An accelerator-based neutron source such as IFMIF [2] is regarded as the most promising one in Japan and the EU. The construction plan of IFMIF is still open due to the large cost impact. In the EU, ENS (Early Neutron Source) or DONES (DEMO Oriented Neutron Source) [3] are considered as possible solutions of the accelerator-based neutron source for DEMO. Also Japan Atomic Energy Agency (JAEA) has a plan of a neutron source for material and component tests using an Linear IFMIF/EVEDA Prototype accelerator (LIPAc) [2] and a lithium test loop [4] for the IFMIF target facility, which are implemented under the Broader Approach agreement between Japan and the EU [5].

2. Proposed Neutron Source System

In the IFMIF/EVEDA project of the Broader Approach activities, LIPAc and the lithium test loop are under going at the Rokkasho Fusion Institute and the Oarai Research and Development

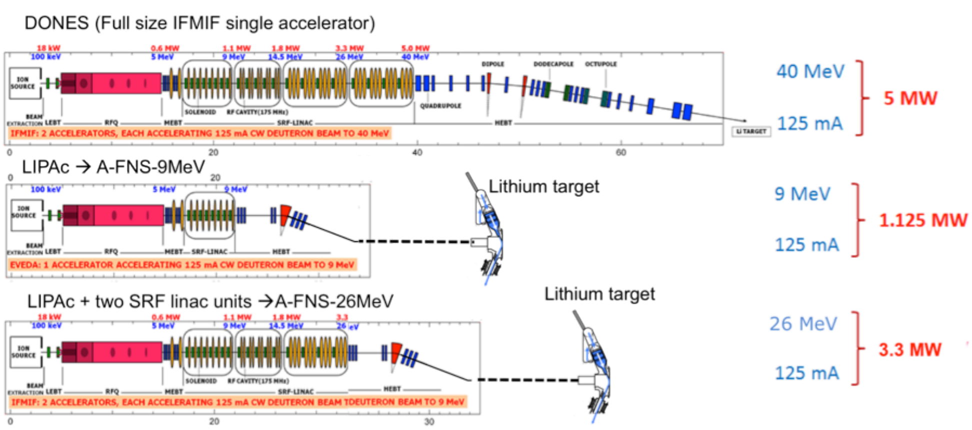

Fig.1. Schematic diagrams of three proposed neutron sources; DONES, A-FNS9 and A-FNS26.

Center of JAEA, respectively. The full size IFMIF consists of two deuteron linear accelerators with 125 mA and 40 MeV deuteron beam each, free surface liquid lithium target with 260 mm in width and 25 mm in thickness, and flow velocity of 15 m/s. Major components of the LIPAc are the injector, the Radio-Frequency Quadrepole linac (RFQ), the Superconducting Radio-Frequency (SRF) linac, which provides a 125 mA and 9 MeV deuteron beam. The lithium test loop has a mockup target with liquid lithium flow of 100 mm in width, 25 mm in thickness, and flow velocity of 10-20 m/s.

The EU proposes a neutron source with single accelerator of full size IFMIF and the liquid lithium target, which is named DONES. JAEA has additionally two options; 1) LIPAc with the liquid lithium target which is named Advanced Fusion Neutron Source 9 MeV (A-FNS-9MeV) tentatively, and 2) LIPAc added two SRF units with the liquid lithium target which is named A-FNS-26MeV (See Fig.1). Here expected performances of three options (DONES, A-FNS-9MeV and A-FNS-26MeV) are discussed.

3. Expected Characteristics and Performance

Deuteron beam range in liquid lithium is 19 mm, 7 mm and 0.9 mm for 40 MeV, 26 MeV and 9 MeV, respectively. The boiling point of lithium is 1327 ºC in 1 atm, however, decreases to 322 ºC in vacuum. The liquid lithium target is curved in order to suppress boiling inside the lithium flow by centrifugal force. In case of A-FNS-9MeV with 125 mA beam to 10 m/s flow of liquid lithium with base temperature of 250 ºC, maximum temperature of the beam deposition layer within 1 mm from the flow surface is expected to be higher than 1300 ºC which is much higher than the boiling point near the surface. So A-FNS-9MeV has to reduce the beam current or increase lithium flow velocity up to ~30 m/s.

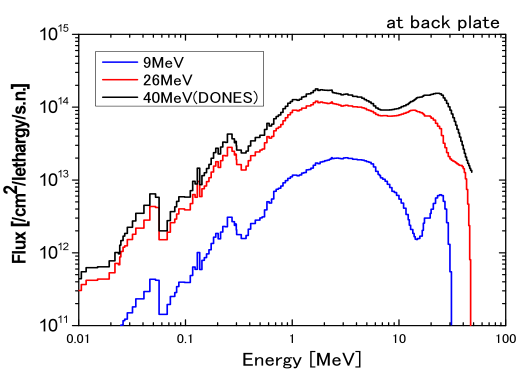

Fig.2. Neutron spectra at the lithium target back plate.

Figure 2 shows neutron spectra at the lithium target back plate calculated by McDeLicious [6] code for DONES, A-FNS-9MeV and A-FNS-26MeV. One of the most important subjects of the material test is transmuted helium effect of the material degradation such as an increase of the ductile-brittle transition temperature (DBTT). As shown in Table I, the ratio of helium production over the number of displacements per atom (DPA) in reduced activation ferritic/martensitic (RAFM) steels of A-FNS-26MeV is very close to 10, which is expected in DEMO blankets, however, that of A-FNS-9MeV is significantly lower than 10, which indicates that the option of A-FNS-26MeV can evaluate the helium effect on blanket structural materials, however, A-FNS-9MeV could not do it.

Table I. Irradiation performance at the back plate

	DONES	A-FNS-26MeV	A-FNS-9MeV
Neutron flux (cm^{-2} s^{-1})	$5.9X10^{14}$	$3.8X10^{14}$	$4.8X10^{13}$
DPA/fpy	25	14	1.5
He production (appm.fpy)	$3.1X10^{2}$	$1.2X10^{2}$	$6.6X10^{0}$
He-prod./dpa	12	8.5	4.4

*fpy: full power year

Also blanket functional test such as tritium release characteristics is one of the major subjects of this neutron source. Assuming the tritium release test module, which is designed for IFMIF, to be installed just in front of the lithium target back plate of A-FNS-26MeV, the tritium production rate and the nuclear heating rate calculated by McDeLicius are 4.5 X 10^{4} Bq/s and 2.3 W/cc, respectively, which are measurable amount with sufficient accuracy.

4. Summary and Prospect

From the point of view of the neutron energy relevance to the fusion neutron, DONES is desirable, however, A-FNS-26MeV is acceptable for blanket functional tests and also material tests for the DEMO development.

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