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Linear IFMIF Prototype Accelerator (LIPAc): Installation activities for Phase-B beam commissioning in Rokkasho

Keitaro Kondo[a,*], Juan Marcos Ayala[c], Benoit Bolzon[d], Philippe Cara[b], Hervé Dzitko[b], Takashi Ebisawa[a], Enrico Fagotti[e], Dominique Gex[b], Roland Heidinger[b], Yosuke Hirata[a], Ryo Ichimiya[a], Yukiharu Ikeda[a], David Jimenez[f], Antti Jokinen[b], Atsushi Kasugai[a], Takayuki Kikuchi[a], Juan Knaster[c], Masao Komata[a], Sunao Maebara[a], Alvaro Marqueta[b], Ivan Moya[b], Shinobu Nishimura[a], Shigeru O'hira[a], Yoshikazu Okumura[c], Mario Perez[c], Guy Phillips[b], Ivan Podadera[f], Giuseppe Pruneri[e], Keishi Sakamoto[a], Francesco Scantamburlo[e], Takahiro Shinya[a], Masayoshi Sugimoto[a], Moises Weber[f]

[a] *National Institutes for Quantum and Radiological Science and Technology (QST), 2-166 Omotedate, Obuchi, Rokkasho-mura, Kamikita-gun, Aomori 039-3212, Japan*
[b] *Fusion For Energy, Boltzmannstr. 2 85748, Garching, Germany*
[c] *IFMIF/EVEDA Project Team, 2-166 Omotedate, Obuchi, Rokkasho-mura, Kamikita-gun, Aomori 039-3212, Japan*
[d] *CEA Saclay, Gif-sur-Yvette 91191, France*
[e] *INFN-LNL, Viale dell'Università, 2, Legnaro 35020, Italy*
[f] *CIEMAT, Av. Complutense, 40, Madrid 28040, Spain*

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ABSTRACT

The construction of the Linear IFMIF Prototype Accelerator (LIPAc) is in progress in order to demonstrate the feasibility of the low energy section of an IFMIF deuteron accelerator up to 9 MeV with a beam current of 125 mA in CW. The next milestone of the project is the so-called Phase-B beam commissioning, and one of the missions is to demonstrate the acceleration of the proton beam up to 2.5 MeV or the deuteron beam up to 5.0 MeV in pulsed mode with a low duty cycle of 0.1% through RFQ. Most of the components and subsystems necessary for Phase-B were delivered by 2016 under the responsibility of Fusion for Energy (F4E) as in-kind contributions of several European institutes, namely CEA (France), CIEMAT (Spain), INFN (Italy), and SCK-CEN (Belgium), and QST is in charge of the installation of the delivered equipment. The installation and check-out of the RFQ subsystem and the RF power system was completed by July 2017, and the RF conditioning of the RFQ cavity started. Also, the installation and the check-out of the important sub-systems for Phase-B, namely MEBT and beam diagnostics, have been completed.

1. Introduction

In a future nuclear fusion reactor, structural materials and functional materials used will be exposed to quite intense flux of 14 MeV neutrons produced by the deuterium-tritium (d-t) reaction. As a neutron source enabling irradiation test of such candidate materials, it was concluded in the early 1970's that an accelerator-based neutron source utilizing deuteron-lithium nuclear reaction was the most suitable, and research and development based on international cooperation has been conducted [1]. The concept of International Fusion Material Irradiation Facility (IFMIF) was established in the Comprehensive Design Report (CDR) compiled in December 2003 under the IEA (International Energy Agency) collaboration. According to that, IFMIF consists of two of 40 MeV, 125 mA high-intensity steady-state deuteron accelerator, a liquid lithium target and an irradiation test facility. The aim of IFMIF is to perform the neutron irradiation at 50 dpa (displacement per atom) per year at maximum, which enables to make an accelerated test of the first wall of a fusion power plant. In order to realize this goal, the accelerator requires CW (continuous wave) operation with the extremely high current mentioned above and high reliability. The IFMIF project is now in the Engineering Validation and Engineering Design Activities (EVEDA) phase under the Broader Approach Agreement between Japan and EU [2]. The purpose of the EVEDA phase is to produce an integrated engineering design of the IFMIF and the data necessary for

* Corresponding author.
E-mail address: kondo.keitaro@qst.go.jp (K. Kondo).

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future decisions about the construction, operation, exploitation and decommissioning of the IFMIF, and also to validate the continuous and stable operation of each IFMIF subsystem. As a part of the activities, the construction of the Linear IFMIF Prototype Accelerator (LIPAc), which is the prototype of the IFMIF deuteron accelerator projected to validate the acceleration of deuterons up to 9 MeV with a beam current of 125 mA in CW, is progressing at Rokkasho, Aomori, Japan. The commissioning of LIPAc is conducted in 4 phases to aim its full specification step by step. The injector commissioning (up to 100 keV) started in 2014 and the designed performance was confirmed in the experimental campaigns in 2015–2017 [3,4], which is so-called 'Phase-A' . The next milestone of the project is to perform 'Phase-B' beam commissioning, which includes an important task to demonstrate the deuteron beam acceleration up to 5.0 MeV through the Radio Frequency Quadrupole (RFQ) Linac, to characterize the beam in pulsed mode at low duty cycle and its characteristic as an interface to the Superconducting Radio-frequency (SRF) Linac. Also, the commissioning of Medium Beam Transport (MEBT) section and the functionality test of beam diagnostics are indispensable in order to proceed to the commissioning of the entire accelerator, which is called 'Phase-C' (pulsed beam) and 'Phase-D' (CW). The nuclear licensing process is also divided into 3 or 4 steps as the beam energy increases to make it easier.

Fig. 1 shows the configuration of LIPAc in the Phase-B commissioning, in which one can see the accelerator in the middle of the figure arranged in the accelerator vault (surrounded by walls displayed in brown), the RF power system equipped in the RF area in the north of the vault, and utilities in the south. Most of components and subsystems necessary for the Phase-B commissioning were delivered in 2014–2016 under the responsibility of Fusion for Energy (F4E) as in-kind contributions of several European institutes, namely CEA (France), CIEMAT (Spain), INFN (Italy), and SCK-CEN (Belgium), and QST has been in charge of the installation of the delivered equipment. In the present paper, the progress of the installation and the check out activities performed in Rokkasho for the accelerator components, namely RFQ, MEBT, beam diagnostics and the RF power system, is described in detail. Some lessons we learnt from the installation, the on-going activities and the prospect of the beam commissioning are explained.

Table 1
RF power system component delivery to Rokkasho.

No.	Components	Date arrived at Rokkasho
1	HV breaker Board (FBR01-10), 10 Transformers (FTR01-10)	14/Jul/2014
2	Common electrical board (APB02)	09/Oct/2014
3	RF module #1&2, 7 HVPSs (FHS01-07), LV distribution board (FCU03-05)	31/Aug/2015
4	2 transformers (FTR11,12)	12/Jan/2016
5	RF module #3	22/Feb/2016
6	RF cooling system #1	04/Apr/2016
7	UPS and White Rabbit board (FCU01,02), Solid state amplifier for MEBT buncher	28/Apr/2016
8	RF cooling system #2	27/Jun/2016
9	RF Module #4, HVPS (FHS08), RF cooling system #3	14/Aug/2016
10	RF cooling system #4	08/Oct/2016

2. RF power system

2.1. Delivery and installation

The radio frequency (RF) power system of LIPAc requires to supply the big RF power of 1.6 MW, continuous wave (CW) to the RFQ cavity, which is a key component in accelerating deuteron CW beam at the huge current of 125 mA. For this purpose, 8 chains of the RF power source with two Tetrodes amplifiers producing 175 MHz, 200 kW and CW are employed [5]. The system is complicated and large scale including electric power distribution equipment and the cooling system. The RF power system was provided to Rokkasho under the procurement responsibility of CIEMAT, Spain. The RF power source module (RF module) was manufactured by INDRA, Spain, and the high-voltage power supply (HVPS) for Anode of the final amplifier Tetrode were manufactured by JEMA, Spain. A part of the equipment was transported first time in the summer of 2014 to Rokkasho, starting from the outdoor components of the power distribution equipment procured by JEMA, and nine different sea transportations followed to complete the system. Table 1 summarizes the date of the arrival for different RF system

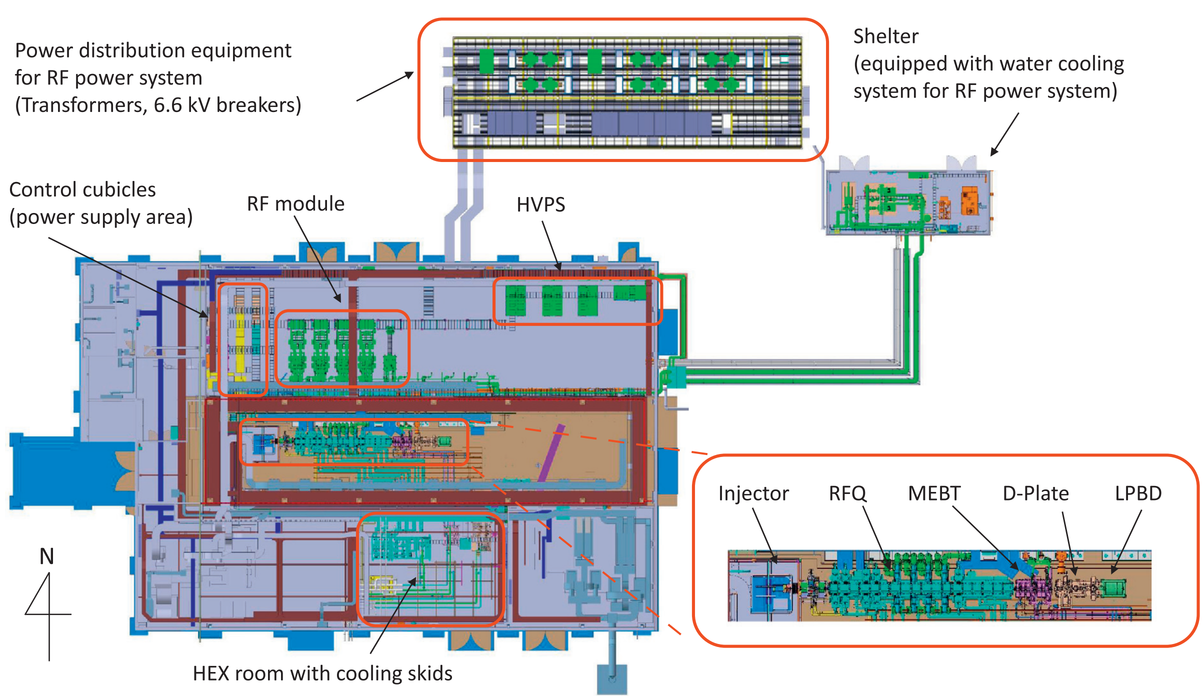

Fig. 1. Phase-B installation of LIPAc to demonstrate the deuteron beam acceleration up to 5.0 MeV.