STATUS OF THE ESS ELLIPTICAL CRYOMODULES AT CEA SACLAY

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Abstract

The first ESS prototype cryomodule with medium beta cavities named M-ECCTD is being assembled at CEA Saclay. The Q curves of the 4 cavities mounted inside the cryomodule are presented, and the four power couplers have been conditioned at high power before their assembly onto the cavity string. Completion of the M-ECCTD assembly outside clean room is in progress as well as the finalization of the RF power test stand preparation. RF power tests of the M-ECCTD will be performed during summer 2017.

CEA is preparing the production of the ESS medium and high beta cryomodules of the series before the test of the M-ECCTD and the contracts for the procurement of the most critical components have already been signed.

INTRODUCTION

The high energy section of the ESS LINAC is composed of 9 medium beta cryomodules at β=0.67 and 21 high beta cryomodules at β=0.86 [1, 2, 3]. The cryomodule design is similar for medium and high beta cryomodules with 4 elliptical cavities at 704 MHz [4]. The nominal gradients are respectively 16.7 and 19.9 MV/m for medium and high beta cavities and the maximum power transferred by the power couplers is 1.1 MW.

The main activities for the development of the ESS elliptical cryomodules are driven by CEA Saclay. The prototyping phase consisting in the design, manufacturing and tests at high RF power of a prototype medium beta cryomodule named M-ECCTD is still in progress within the French-Swedish collaboration agreement and will end by the autumn 2017. The production of the 30 cryomodules of the series by CEA is one of the main French in kind contribution for the ESS accelerator construction and the preparation of this production is starting before the completion of the prototyping phase.

The status of the M-ECCTD prototyping and of the preparation of the production of the series is presented in this paper as well as the organization of the collaboration and the role of the different ESS partners working with CEA.

MEDIUM BETA PROTOTYPE CRYOMODULE M-ECCTD

A Technology Demonstrator M-ECCTD is being developed in a collaboration of CEA/Irfu and CNRS/IPNO [3]. General layout has been presented in previous papers [4]. The design of the cryomodule is based on the SNS principle with a spaceframe holding the four cavities and the thermal shield inside the vacuum vessel (Fig. 1). The aluminium thermal shield is cooled by GHe flowing at 19.5 Bars and 40 K. The power couplers have only one ceramic window at room temperature and are in vertical position below the cavities. The magnetic shields are fixed on the cavity helium tanks and their temperature is not controlled. The helium tanks of the cavities are in titanium and the diphasic pipe above the tanks is also in titanium welded to the tanks. The design of this diphasic pipe with large radius and equipped with 2 burst discs at Ps=1.04barg allow keeping the cryomodule compliant with the article 4.3 of the PED.

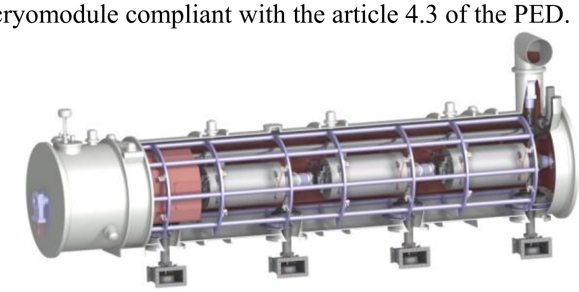

Figure 1: General layout of the ESS elliptical cavity cryomodule.

The cavity string of this prototype M-ECCTD is composed of 3 cavities developed by CEA Saclay [5] and 1 cavity developed by LASA [6]. Q curves of these cavities equipped with the helium tank are shown on Fig. 2.

CEA cavities have been prepared in laboratory at Saclay (field flatness, BCP treatment, HPR rinsing and assembling for test in vertical cryostat) except the hydrogen heat treatment done at ZANON, and the tests in vertical cryostat was done at CEA. In order to limit the delay of the planning CEA decided to mount in the M-ECCTD the first 3 cavities tested before solving the problem of performance limitation observed.

ISBN 978-3-95450-182-3

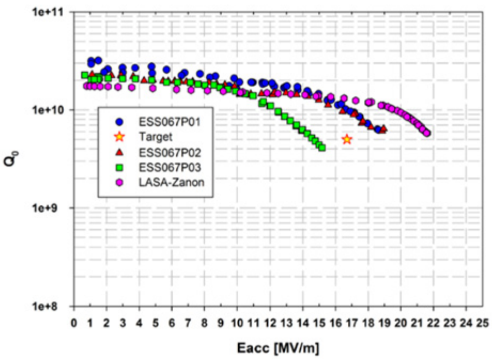

Figure 2: Q curves of the cavities mounted in the M-ECCTD.

These 3 cavities show high Q0 values at low field but one of them doesn't reach the ESS performances, the two others show high field emission above 10 MV/m. The LASA cavity prepared by the ZANON Company under supervision of LASA and tested at INFN reaches very high gradient. This demonstrates the high quality of the cavity preparation in industry trained for large cavities production.

The high power of 1.1 MW of the ESS elliptical cavities power couplers is challenging. The design chosen is the same as the HIPPI coupler already tested at Saclay up to 1.2MW on a 704MHz cavity at beta=0.45 and with a duty cycle of 10% [7]

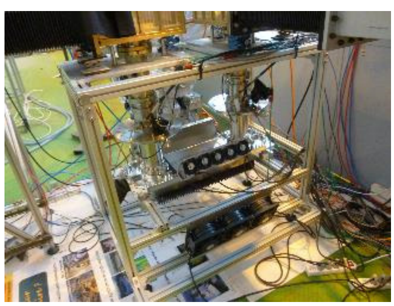

Figure 3: A pair of couplers mounted on a coupling box during the RF processing at room temperature.

Two pairs of couplers were mounted on the M-ECCTD after RF processing at room temperature up to 1.2 MW in transmitted and in full reflexion conditions with the ESS pulse characteristics (see Fig. 3 and 4) [8].

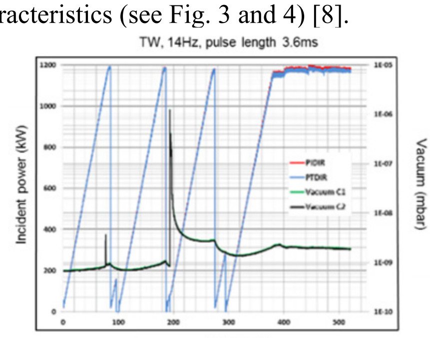

Figure 4: Vacuum pressure vs RF power during RF processing of a pair of power couplers in TW mode at 14Hz and the maximum pulse length of 3.6 ms.

All cryostat components of the cryomodule have been designed and delivered by CNRS/IPNO except the piezo tuners and magnetic shields provided by CEA. CEA developed the tools for the assembly inside the large ISO4 clean room previously used for the XFEL cryomodules. A clean workshop has been built and equipped for the assembly outside the clean room.

CEA started the assembly of the M-ECCTD (Fig.5) after a blank assembly of the cryomodule with a mock-up cavity and a mock-up coupler.

Figure 5: Assembling of the coupler on cavity (left) and of the cavity string (right) inside the ISO4 clean room.

The procedures applied for the assembly in clean room benefit from the experience of the assembly of the XFEL cryomodules. Presently the clean room assembly of the cavity string is finalized and the assembly outside the clean room has started. The cryogenic helium diphasic tube that is in titanium has been welded on the helium tanks of the cavities and the piezo tuner have been mounted (Fig. 6).

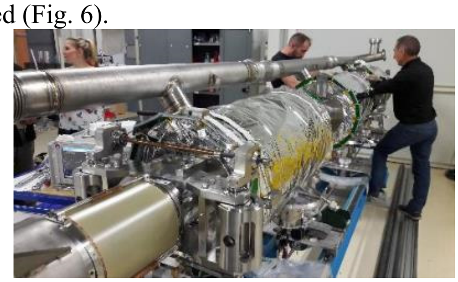

Figure 6: Piezo tuners assembly after the helium diphasic pipe in titanium has been welded.

The cryomodule assembly is in progress (Fig.7) and it will be completed by the end of June.

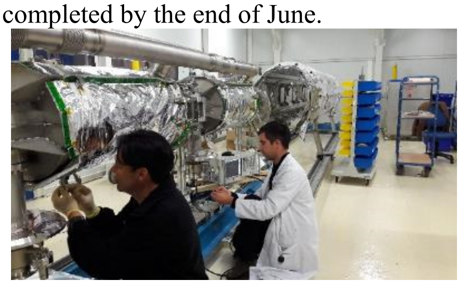

Figure 7: Last operations on the cavity string are in progress before insertion inside the thermal shield that has already been prepared (behind the cavity string).

The test stand with high RF power is now close to completion. The main cryogenic pipes and wave guides are installed. The installation and checks of the control command system (EPICS) and of the racks are close to the end. The tests of the M-ECCTD at cold and with high RF power will start in July 2017. A 1.1 MW RF power source at 704 MHz with 3.6 ms pulses at 14 Hz (Fig. 8) will allow feeding one or two cavities maximum at the same time.

The test plan covers all usual topics among which cryogenics loads measurements, cavities displacements during pumping and thermal cycles, RF power tests of cavities up to the maximum power (1.1MW) and maximum cavity accelerating gradient, linearity of the cavity frequency tuning, Lorentz forces detuning compensation with the piezo tuner.

Figure 8: The RF 1.1 MW power source at 704MHz pulsed at 14 Hz, 3.6 ms used for the couplers RF processing and for the tests of the M-ECCTD.

After the RF power tests of the M-ECCTD at Saclay, this prototype cryomodule will be used for the test of the transportation from Saclay to Lund.

CRYOMODULES OF THE SERIES

In parallel to the M-ECCTD activity, CEA is preparing the production of the cryomodules of the series. The scope of the CEA In Kind Contribution is the following:

- A complete H-ECCTD prototype cryomodule with tests at high RF power in Saclay laboratory.
- The components for 30 cryomodules (9 medium and 21 high beta) except cavities.
- 120 power couplers and the RF processing at room temperature
- Installation of a 1.5MW RF power source at 704MHz for the power coupler processing.
- The assembly of the 30 cryomodules of the series in the clean at Saclay.
- Tests at high RF power type in Saclay laboratory of the 3 first cryomodules of each type (3 medium and 3 high beta).

The production of the 36 Mbeta cavities is an In Kind Contribution of Italy (INFN/LASA) and the production of the 84 Hbeta cavities is an In Kind Contribution of UK (STFC) [2]. All cavities will be delivered to CEA already tested in vertical cryostat and ready to be mounted inside the cryomodules.

CEA will place 40 contracts of more than 1M€ among which 29 are for the cryostat components. In order to respect the ESS tight time schedule CEA already signed the contracts for the most critical components before the test of the M-ECCTD: vacuum tanks, power couplers, spaceframe and thermal shield, tuners. Several other tendering are launched and will be placed soon such as magnetic shields, gaskets, RF cables.

The RF power source delivering a maximum power of 1.5MW has been ordered and will be installed near the first source by the end of 2017. The use of 2 RF sources at 704MHz will allow the processing of the 120 power couplers in parallel to the tests of the 2 prototype cryomodules M-ECCTD and H-ECCTD as well as the 3 first cryomodules of each type assembled at Saclay.

A dedicated clean workshop housing 2 benches for the coupler processing is going to be built close to the RF power sources. This room will be equipped with an oven for baking at 170°C the coupler pairs mounted on the coupling boxes before the RF processing.

ESS Lund will perform the final acceptance tests of all the medium and high beta cryomodules at high power before installation on the beam line.

CONCLUSION

The assembly of the first ESS prototype cryomodule with elliptical medium beta cavity M-ECCTD will be completed by the end of June 2017. The tests at high RF power will be performed during summer 2017.

In parallel to the prototyping activities CEA is preparing the production of the 30 medium and high beta cryomodules of the series. CEA already launched the contracts for the procurement of the most critical components of the series requiring the longest time production such as the vacuum tanks, space frame, thermal shield, and power couplers. The preparation of the infrastructure for series production is in progress for the storage of the components, for the RF processing of the power couplers, for the cryomodules assembly and for the RF power tests of the cryomodules at 2K.

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ISBN 978-3-95450-182-3