

# STATUS OF E-XFEL STRING AND CRYOMODULE ASSEMBLY AT CEA-SACLAY

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## Abstract

As In-Kind contributor to the E-XFEL project, CEA is committed to the integration on the Saclay site of the 100 cryomodules (CM) of the superconducting linac as well as to the procurement of the magnetic shieldings, superinsulation blankets and 31 cold beam position monitors (BPM) of the re-entrant type. The assembly infrastructure has been renovated from the previous Saturne Synchrotron Laboratory facility: it includes a 200 m<sup>2</sup> clean room complex with 112 m<sup>2</sup> under ISO4, 1325 m<sup>2</sup> of assembly platforms and 400 m<sup>2</sup> of storage area. In parallel, CEA has conducted industrial studies and three cryomodule assembly prototyping both aiming at preparing the industrial file, the quality management system and the commissioning of the assembly plant, tooling and control equipment. In 2012, the contract of the integration has been awarded to ALSYOM. The paper will summarize the outputs of the preparation and prototyping phases and the status of the up-coming industrial phase.

## INTRODUCTION

The 17.5 GeV superconducting RF linac of the E-XFEL project [1] will comprise 100 cryomodules (cf fig.1), after the injector module. These twelve-meter long cryomodules, deriving from the FLASH technology, include a string of eight 1.3 GHz RF cavities with an average gradient of 24 MV/m, followed by a BPM and a superconducting quadrupole.

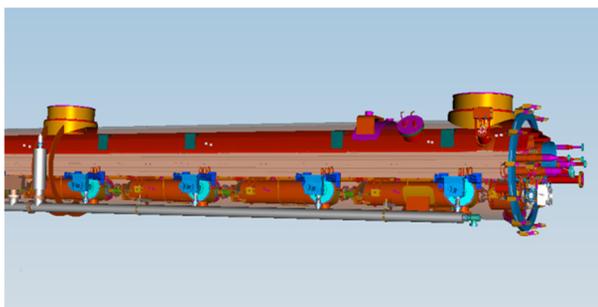


Figure 1: XFEL Cryomodule 3D-model

This string is closed by two gate valves at both ends. Within the Accelerator Consortium (AC), CEA is committed to the assembly of the 103 cryomodules over 2013 to mid-2015 with the goal to deliver one cryomodule per week to DESY for RF acceptance. Strategic decisions, shared by the AC, were taken in 2008 first to host the assembly plant on CEA premises at Saclay, using the former Saturne Synchrotron Laboratory

accelerator and experimental halls, second to subcontract the 103 modules, assembly work, including 3 pre-series modules, to an industrial company for. The layout of the assembly plant (see Fig. 2), was optimized by breaking down the assembly work in seven successive blocks of one-week procedures, leading to one clean room complex for coupler and string assembly, and five cryostating workstations for the remaining cryostating work, including alignment and control operations. To allow for a fluid circulation of the cryomodules along the assembly chain even when a repair is needed at one workstation, each workstation, but the vacuum vessel cantilever (see Fig. 3), has been doubled to offer module parking possibilities.



Figure 2: Layout of the XFEL infrastructure



Figure 3: Vacuum vessel and cold mass on the cantilever

## OUTPUTS FROM THE PREPARATION PHASE

To ensure the integration of 103 CM at the rate of one cryomodule per week, CEA has set up a program to form

an expert team and to commission the facility. This program includes a training phase, a prototyping phase and the industrial phase.

#### *Training phase:*

In 2007, CEA and DESY have started the transfer of the knowledge by a period of observation by CEA personnel at DESY (M3 CM for FLASH) followed by a “hands-on” assembly period where CEA personnel participated in the assembly of the FLASH M8-PXFEL1 CM with the DESY team.

#### *Pre-industrial studies:*

Meanwhile, CEA has conducted industrialisation studies aiming at defining industrial equipment and methods for the cryomodule assembly. The first study has determined the workflow from the storage to the shipment, with cavity reception, clean room assembly, roll-out, alignment, vessel roll-over and coupler assembly (see Figs.2-7). The areas have been dimensioned accordingly and matched to the infrastructure which was renovated from the previous Saturne Synchrotron Laboratory facility: the 200m<sup>2</sup> clean room complex with 112 m<sup>2</sup> under ISO4 allows us to assemble the couplers to the cavity and two cavity strings in parallel; the *cryostating* will be held on the 1325 m<sup>2</sup> of assembly platforms and 400 m<sup>2</sup> are dedicated to storage.



Figure 4: PXFEL2\_2 in the ISO4 clean room facility

The first fabrication file included assembly procedures with task description, duration and manpower skills definition. It included also the big tools drawing updates, tasks schedules and risk analysis. The cost estimate of the 103CM integration has been estimated. The outputs of this first study lead CEA to launch the big tool fabrication, speed-up the infrastructure set-up, establish the quality insurance plan and start the prototyping phase where CEA team is training in house on assembling 3 CM using its infrastructure and tools.

The second more detailed study finalized the tools such as the clean room tools specific to CEA infrastructure, the detailed assembly procedures with tools in use, duration of the task, incoming and outgoing parts; the parts flow has been consolidated, the stock needs have been evaluated. This study has defined the product breakdown structure, updated the risk analysis and detailed the

schedule in tasks. The outputs of this study were used to place the call for tender for the 103 CM integration.

#### *Prototyping phase:*

The prototyping phase consisted of the assembly of 3 CM (namely PXFEL2\_1, PXFEL3\_1 and PXFEL2\_2) at CEA by both CEA and DESY staff allowing qualifying the team, the tools and the infrastructure.

The infrastructure was equipped with the services and fluids for the CM assembly. Big tools such as girders and pillars (cf Fig 5) have been manufactured ahead of time and commissioned along the prototyping phase.



Figure 5: PXFEL2\_2 cold mass and string hooked to the girder in the Roll-Out area

Small tools, especially those dedicated to clean room assembly (cf Fig. 6), were manufactured and commissioned during the prototype phase. Ionized gun and particle counters for clean room assembly were ordered and used to insure the required low level of particles on the part to be assembled (less than 10 particles over 1 minutes of 0.3 mm on the part to be assembled).

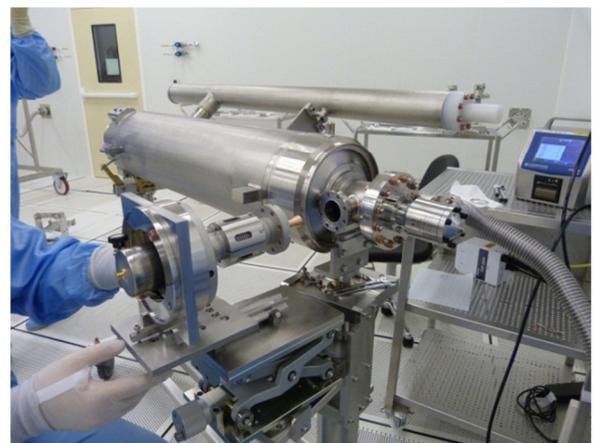


Figure 6 : coupler to cavity assembly in the clean room with tools (elevator table and coupler holding) and particle counter

Vacuum groups, equipped with RGA and slow pumping-venting system, have been installed on the clean room wall and in the coupler hall. Those groups, provided

by DESY, are designed to reduce the particles migration when pumping or venting a cavity or a coupler.

CEA has designed specific vacuum groups with a turbo pump and gauge attached to the cavity in the clean room and the primary pumps outside the clean room. Those groups are dedicated to the leak detection and venting of the cavity during the assembly. They have been ordered for the XFEL CM assembly.

The tests and controls have been detailed (RF, mechanical, vacuum, electrical), implemented and validated. The automated RF and tuner test bench have been developed for systematic measurements and recordings as well as the alignment and particle counter software. They have been tested on the prototypes.



Figure 7 : CM after warm coupler assembly

The assembly procedures have been tested during a first assembly, then modified according to CEA's infrastructure and tools and rechecked on a last assembly for repetitive tasks. The part workflow from the reception to the assembly halls has been validated. Improvements on a few workstations are under evaluation, aiming at saving assembly time.

During the prototype phase, CEA and DESY established the Manufacturing Bill Of Material (MBOM [2]) which is collecting, recording, and archiving the complete mandatory fabrication information. It is focused on the parts that are needed to manufacture a CM at CEA. The MBOM also includes information about how the parts relate to each other, the inspection to be performed, the tests to be recorded, the assembly procedures, the documentation etc... The XFEL cryomodule MBOM contains roughly 500 lines i.e. 500 elements are assembled on a CM at CEA.

### PROCUREMENTS

CEA is in charge of the procurement of the 800 cavity magnetic shields. The awarded company proposed some closing improvements as well as a new Cryophy™ material which was qualified on the CM prototypes.

Precut and assembled multilayer blankets for the 2K and 70K superinsulation have been ordered: they facilitate the assembly and reduce its duration. Cryogenic loss measurements on the prototype modules qualified them for the series.

CEA is also in charge of 31 cold re-entrant BPM (cf. figure 8). These BPM have been studied and prototyped

at CEA [3], and tested on FLASH. The integration with the cold quadrupole is done at DESY. The electronics developed by CEA in collaboration with PSI will be implemented in the modular BPM unit [4].

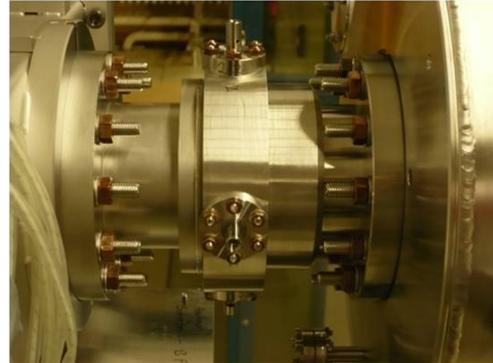


Figure 8 : BPM installed on PXFEL3\_1

### INDUSTRIAL PHASE

The contract for 103 CM integration has been awarded to ALSYOM in July 2012. The first phase (until Dec 2012), consists of the observation by ALSYOM of the assembly by CEA of the first pre-series cryomodule (XM-3) and the deployment of their industrial method based on the outputs of the prototyping. It also includes the set-up of the storage area, the ERP (entreprise resource planning) parameterization and the consumable parts ordering. The second phase is the training of the company team attended by the CEA team on the assembly of the second and third pre-series modules XM-2 and XM-1. From XM1 on, ALSYOM will be in charge of the series module assembly. A ramp-up period of six months is foreseen to reach the production rate of 1 CM per week. Based on quality assurance and quality control, the Acceptance Data Package (ADP) will support the first step of CM acceptance by CEA. It includes the certificate of conformity, the "as-built" configuration, the traveler, and the test and non-conformities reports. PXFEL2\_2 CM ADP was built following our experience and needs, and it was delivered to DESY with the CM on Sept 4<sup>th</sup>, 2012 for approval. The second CM acceptance stage will be based on the RF test at DESY.

### CONCLUSIONS

The CM factory is ready to start the assembly of the XM-3 pre-series XFEL cryomodule on September 17<sup>th</sup>, 2012.

### REFERENCES

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