Industrialization of E-XFEL string and module assembly at CEA-Saclay

Preparation work
Lessons learnt
Cost reduction
17/09/2012 : Let’s start
CEA contribution

- CEA contributes to the E-XFEL Cold Linac construction through String Assembly (WP9), Module Assembly (WP3) and BPM (WP17)
- Accelerator Module Assembly (WP3-WP9): assembly of 103 accelerator modules with 1 per week throughput! operated by an industrial contractor on the Saclay site.
Phases of the project

- **Phase 1: 2007-2008**
  - Preliminary study subcontracted

- **Phase 2: 2009-2010**
  - Preparation of Infrastructure and Tooling

- **Phase 3: 2010 – 2012**
  - Pre-industrial study
  - Prototyping: Training and Commissioning at Saclay with XFEL Prototype Modules (PXFEL2 and PXFEL3)
  - Leading to Restricted Call for Tender signed in July 2012

- **Phase 4: July 2012 → Q1-2015**
  - XFEL module assembly by industry operator
Phase 1: Overview of the Assembly Buildings

Clean rooms
Assembly halls
Offices
Warehouse

XFel Village

Bldg 124 North
25x15 m²

Bldg 126 North
40x11 m²

Bldg 126 South
30x17 m²

Court Yard

©GoogleMap
Phase 1: Assembly Hall: Workstations

the XFEL Village

Coupler Area CO-WS1 & 2
Warehouse
Alignment Area AL-WS1 & 2
Roll-out Area RO-WS1 & 2
Clean room Area CO-WS1 & 2
SA-WS1 & 2
Reception Area REC-WS1
Shipment Area SH-WS1 & 2
Cantilever Area CA-WS1
Phase 3: Pre-industrial study and Prototyping

- Ajilon was subcontracted to perform the pre-industrial study
  - Tools Definition
  - Assembly Procedures with the non mechanical operations
  - Schedule
  - PBS – EBOM
  - Risk Analysis
  - Interruption Scenarios
  - Inventory Management
  - List and implantation of Services and Fluid Distribution
  - Listing of Parts and Its Packaging
  - Description of Reception Process & Controls
  - Using experience gained at DESY
Phase 3: Pre-industrial study and Prototyping

• Get the « Factory » ready:
  – Implement the pre-industrial study
  – Check the infrastructures
  – Check the tools
  – Check the procedures
  – Train the CEA-IRFU team
  – Prepare all the documentation templates
  – Set-up the QA/QC and MBOM
  – Feedback from the assemblies

• Assembly of 3 cryomodules over 2 years (T0=august 2010) : PXFEL3_1, PXFEL2_1, PXFEL2_2
Phase 3: Lessons from Assembly Prototyping

PXFEL3_1 CMTB Test

Cavities gradient limits

All cavities except C7 are limited by the breakdown

Cavity tests:
- PXFEL3 (10Hz)
- Vertical (CW)
- CMTB (10Hz)

$E_{ACC}$ [MV/m]

1 - Z140  2 - Z97  3 - Z101  4 - Z104  5 - Z134  6 - Z135  7 - Z138  8 - AC124

FE  HOMC1 not tuned  high losses

07/11/2012  C. Madec - TTC 2012
Phase 3 : Lessons from Assembly prototyping

• PXFEL3_1 : cavity 1 (FE) and cavity 8 (HL) do not reproduce their VT performances. The causes are not identified:
  – coupler contamination through common conditionning waveguide box ?
  – particulate contamination during string assembly ?
  – shocks during transport CEA-DESY: (4g on frame,1g on cryomodule) + (2g on frame ,2g on CM) events ?

⇒ Still an open question

• PXFEL3_1 : cavity 7 HOM2 badly tuned :

⇒ a successful RF measurement and HOM tuning campaign took place on PXFEL2_2 cavity string during Week 18, with the help of DESY and AMTF colleagues.
Phase 3: Lessons from Assembly prototyping

• PXFEL2_2:
  – Leak on cavity 6 helium vessel (isolating vac and He circuit)
    - No exchange at CEA because of time constrain for XM-3
    - Not full penetration welding between the cones and the cavity.
    - For serie production, full penetration welding

Leak rate on cavity AC121 rises to a value higher than 1 e-5 mbar.l.s⁻¹
Phase 3: Lessons from Assembly prototyping

- PXFEL2_2:
  - In situ leak appeared at the leak test of the cavity string before shipping (acceptance criteria):
    - leak detection before roll-out \(10^{-10}\) mbar.l.s\(^{-1}\)
    - leak rate \(7.8 \times 10^{-8}\) mbar.l.s\(^{-1}\)
    - discovered on cavity 6 CF 16 PU MC leak
    - under investigation at DESY
    - Verification of the tightening on the coming couplers?
Phase 3 : Acceptance Data Package

• assembly procedures including tests and controls
• traveler
• Templates for controls, tests, reports

Acceptance Data Package:
the certificate of conformity, the “as-built” configuration, the traveler, the test reports the non-conformities reports.
The coupler antenna is tilted in the horizontal plane, the coupler being in the support frame ready for connection to the cavity. The bellow holders were in position and tighten.

Reference documents:

The tilt of antenna axis was estimated at the half of the slot flange (for the leak test) i.e. 2.5 mm at the top of the antenna the tilt was about approximately 4 mm (cf. drawing page 4).

CORRECTIVE ACTIONS (equipment concerned by NCR/CR):

On Friday 17th, we dismounted the coupler AC3C2 from the cavity Z141 and checked the antenna (pictures page 2, during disassembly). The coupler is now mounted back on a TWG.
## Phase 3 : MBOM

It is collecting, recording, and archiving the complete mandatory fabrication information. It is focused on the parts that are needed to assemble 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.

Example of information : reference of the drawing, WP leader in charge of the supply serial number ... (54 columns, 500 lines)

- configuration recording of each cryomodule
- Arborescence documentaire de l'ADP sous EDMS (base documentaire géré par DESY)
MBOM on EDMS

Test report templates
Assembly procedure

QR Code identifying the part and linking it to the MBOM
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Phase 4 : industrial phase

Contract for 103 CM integration awarded to ALSYOM in July 2012.

• The first phase (from Sept 17\textsuperscript{th}, until Dec 2012), consists of :
  – the observation by ALSYOM of the assembly by CEA of the first pre-series cryomodule (XM-3)
  – the deployment of their industrial method based on the outputs of the prototyping
  – the set-up of the storage area,
  – the ERP (entreprise resource planning) parameterization

• The second phase (June 2013):
  – training of the company team attended by the CEA and DESY team on the assembly of the second and third pre-series modules XM-2 and XM-1.

• The third phase : From XM1 on (2013),
  – ALSYOM in charge of the series module assembly.
  – six months ramp-up period to reach the production rate of 1 CM per week.
Cost reductions

• Preindustrial studies
• Team training

• Cavity magnetic shields : proposed some closing improvements and 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.
• Vacuum pumping system in the clean room : reduces time from 3/4h to 1/4h
• Hardware for the clean room assembly : savings in prep time
• Alignement software : savings in time, limit errors
• Rf bench : savings in time, limit errors
• Welding :
  – Welding leak tightness : duration reduced by using the CERN technology (only the detection of the welded area) : reduces pump and purge to lower He background
  – « Paint » test crack in the welds TUV vs Xrays of the weldings.
Conclusions

• Factory ready

• Cost reductions

• Alsyom gets started – observation of XM-3
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