XFEL
String and Module Assembly at CEA-Saclay
WP03-WP09

O. Napoly, CEA-Saclay, Irfu/SACM
Outline

• Status of Assembly
  – Assembly schedule
  – RF tests
• Acceleration of production
• Conclusions
CEA contributes to the XFEL Cold Linac construction through String Assembly in Clean Room (WP9) and Module Assembly (WP3)

↓

Accelerator Module Assembly assembly of 103 accelerator modules with 1 per week throughput!

operated by an industrial contractor on the Saclay site.
The nominal assembly time of 7 weeks has been reached with XM15.

With 7 workstations in parallel, this means that all organisation / reception / assembly / test / transfer / documentation work for one cryomodule is concentrated in 40 hours (1 week), actually ~1800 man.hour labor

about 33 FTE from Alsyom-SEIV
about 10 FTE from CEA

Versatility is needed: no ‘groups’ like RF, Cryo, Vacuum, etc…for 30 FTE

To comply with French labor regulation, we now aim at 35 hours!
Status of Assembly: 20 cryomodules delivered to DESY

The nominal throughput of 1 module per week has been reached since XM12 (24/09/2014). Assuming 1 CM/week from then on:
- XM24 shipped end of 2014
- XM71 shipped end of 2015
- XM82 shipped end of March 2016
- XM100 shipped 2\textsuperscript{nd} August 2016 (w30)

Input:
- 8 days off at Xmas 2014 and 2015
- 2 weeks Clean Room maintenance in 2015
- 1 week Clean Room maintenance in 2016
- 2 days work in SH-WS (shipment area).
Status of Assembly: 4-day throughput in sight

Assembly time per workstation as of 16/10/2014

Assuming 1.25 CM/week from end of November 2014 (throughput of 1 Module / 4 days):

- XM25 shipped end of 2014
- XM83 shipped end of 2015
- XM98 shipped end of March 2016
- XM100 shipped 12 April 2016

Input:

- 8 days off at Xmas 2014 and 2015
- 2 weeks Clean Room maintenance in 2015
- 1 week Clean Room maintenance in 2016
- 2 days work in SH-WS (shipment area).
Cryomodule Performance

CEA is concerned not only by the rate of production, but also by the quality of the production:

Warm coupler overheating crisis revealed
- lack of QC on WIC after RF conditionning
- weak specifications on central screw
- assembly errors on central screw and push-rod screws

Corrective actions should be effective.

Gradient crisis is under investigation.

Other milder mis-fabrications were discovered on tuners, alignment devices, supports, etc…

All modules (except XM-3 and XM-2) needed significant repair work before or after the AMTF RF tests.
Status of Assembly:
12 cryomodules tested at AMTF DESY

- Integrated over 12 modules: +8% above specs, -14% below VT gradient
- Four modules lost about 50-60 MV: XM4, XM6, XM9 and XM10: main cause is early quench, but also large field emission.
- XM8 is parked after a leak detected on the 2K LHe circuit. Investigations will follow.
Cavities 4 and 7 have very strong field emission

- Vert. test average: 28.3 MV/m
- Module test average: 20.0 MV/m by pairs
- Module test average: 25.0 MV/m by single cavity power distribution

No significant incident reported on XM9 string assembly!
XM9 Incident at Cavity Reception

About 3g vertical acceleration recorded during Hambourg-Saclay cavity transport, which included CAV0048, CAV0083 and CAV0617 (actually all XM9 cavities except CAV0067).
XM9 Incidents at Cold Coupler Assembly

CAV00617

Copper burr on the angle valve flange: minor incident.
Small dents on CAV0617 to CAV0083 bellow: minor incident?
XM10 RF Test Results at AMTF

This plot compares ‘vertical apples’ with ‘horizontal oranges’
XM10 RF Test Results at AMTF

Cavities 2, 3 and 5 have very early quenches

- Vert. test average: 28,8 MV/m
- Module test average: 22,6 MV/m by pairs
- Module test average: 25,8 MV/m by single cavity power distribution
- XFEL specification: 23,6 MV/m
XM10 Incidents on Cold Coupler Assembly

Both couplers were connected to the same TWG (travelling wave guide for conditionning) and have been returned to LAL:

**Question:** was the cavity n°3 open during the treatment of this non-conformity?

**Answer from Alsyom:** No; **answer from CEA:** quite possible!

Coupler THRI-CP-258 with a copper particulate in front of Cavity n°3
XM10 Incidents on String Assembly

The three non-conform components have been accepted after corrective actions.

Gate valve with tape: cleaned with isopropanol

Cavity n°2 blind flange with one rusty washer: cleaning with isopropanol and top-gun, control with particle counter

Bellow between cavity n°2 and cavity n°3: cleaning with top-gun, control with particle counter
XM10 Incidents on String Assembly

One filtering fan unit was damaged (electric shutdown) in April and changed in July. A ‘desy-graded’ mode of string connection was used for XM8, XM10 and XM12.
XM10 Incidents at Roll-out Assembly

Cavity n°2: dent on the coupleur bellow

The dent might have been caused by the assembly of the part linking the two half 4K-interfaces.
Alsyom had modified its internal management organisation and staffing:

Management: 8 pers.
Operators: 25
Total Alsyom: 33
SEIV support: 2

4 ‘volants’ provide versatility on their area

Exact estimate from CEA-DESY ‘Expert Group’ in 2009!!
Progress: Non-Conformities

Number of non-conformities per modules

Répartition des Non-Conformités par origine (Sept-Oct 2014)

Breakdown of non-conformities
This leak introduced a delay of 3 days for the repair and the inspection by DESY and TUV.
Still XM19 will be shipped on week 46, with one day of delay w.r.t. the original plan.

Note that week 46 includes only 3 working days but this will be compensated.
Progress: Titanium Welding

Level of quality reach per cryomodule

- Welding by DESY
- Welding by ALSYOM

Number of welds per level of quality

Cryomodule

- XM4
- XM5
- XM6
- XM7
- XM8
- XM9
- XM10
- XM11
- XM12
- XM13
- XM14
- XM15
- XM16
- XM17
- XM18
- XM19
- XM20

- US cleaning of bellows
- Seamless tubes on cavity tanks
- Seamless tubes on cavity 1 extension

5 November 2014
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Progress: Titanium Welding

Three repair campaigns have been needed for XM11 !!
⇒ DESY took over the welding work for XM11-4, XM12, XM13-(1&2), XM14(1&2).
⇒ Immediate success to level 1, has a big impact on assembly schedule on the Roll-out workstation.

From XM18 & XM20, SEIV is now qualified and able to weld at level 1.
Progress: Titanium Welding

Porosity problem remained from the longitudinal weld (16/76) of the ‘cavity1 extension pipe’ to cavity 1 upstream pipe.

At CEA:

• X-Ray radiography contract with SGS from XM15, including X-Ray of repairs within 24h, accepted by SGS.
• Lead protections in place allow for stand-alone radio campaigns since XM14

Are we entering the ‘pacific ocean’ of routine operation, after Cape Horn?
Acceleration of Production

• The nominal production rate has been established.

• 25% higher throughput is feasible but not yet solid.

• Acceleration of production is aiming at consolidation of 4 day-throughput

• Many fabrication mistakes have been detected at AMTF, including large cavity RF degradations and tuner bad assemblies.
Acceleration of Production

Actions on short term:

1) Pre-fabricated et reusable devices for the leak-check of
   • the cavity string connections → delivery of one prototype on
     19/09/2014, needed adjustment, 4 units under fabrication
   • the cold coupler pairs in the clean

2) Realization of gate valve support for its assembly on cold-coupler WS:
   Design and fabrication taken over by Alsyom, used for XM22.
Acceleration of Production

Actions on the short term:

• Reinforce the quality control team to detect non-conformities, if possible ahead of assembly, and to document them

• With INFN, fix the low reliability of the tuner electric control bench and commission a second bench to avoid its transfer across the XFEL Village.

Actions on the medium term:

• Test and implement a solution for faster cavity string connections by anticipating individual cavity venting on the coupler assembly workstation

• Commission the second workstation for warm coupler assembly
Acceleration of Production

Proposals for the short term:

• Cutting coupler holes in the 4K blankets is not an industrial solution, especially when the blanket hangs from the wrong side.

→ Go for pre-cut blankets
Acceleration of Production

Proposals for the medium term:

• Fully automated vacuum systems would reduce risk and increase productivity: 4 functionalities PUMP, VENT, FLUSH, RGA

• Welding Titanium bellows with pure Argon, instead of He-Ar, would save the long and uncertain time needed to pump and N2 purge of the LHe tank before the Helium leak test by external accumulation.
Conclusions

The nominal production rate 1 CM/week is reached.

The next fight is cryomodule performance, avoiding repair work.

Alsyom is currently working on a plan for acceleration of production with the goal to consolidate the 4-day throughput organisation:

• Final plan presented on 4 November to CEA
• CEA is currently analyzing this plan and its consequences on cost and manpower at CEA
Skip the trucks, cryomodule will be transported all the way with Paris metro tunnel extension (line 14) to XFEL!!
Back Up Slides: XFEL Village Infrastructure
Overview of the Assembly Buildings

Clean rooms
Assembly halls
Offices
Warehouse

©GoogleMap
Assembly Hall: Workstations

- Warehouse
- Coupler Area CO-WS1 & 2
- Cantilever Area CA-WS1
- Alignment Area AL-WS1 & 2
- Reception Area REC-WS1
- Clean room Area CC-WS1 & 2
- Roll-out Area RO-WS1 & 2
- Shipment Area SH-WS1 & 2

the XFEL Village

5 November 2014

O. Napol, XFEL MAC
Organisation of Work Stations

1. **Clean Room Cold Coupler Area** (IS04-CC-WS1)
   - Cold coupler assembly (x8)
   - Leak check of caity-coupler connection (+RGA)

2. **Clean Room String Assembly Area** (ISO4-SA-WS1, ISO4-SA-WS2)
   - String connections (1 gate valve + 8 cavities + 1 Qpole unit)
   - Leak check of string and N₂ venting (+RGA)

3. **Roll-out Area** (RO-WS1, RO-WS2)
   - HOM adjustment, magnetic shielding, T-sensors (x6)
   - Tuner assembly (x8), coupler 4K and 80 K shields
   - 2 Ph-tube welding, NCT (LT, PT, RT)
   - Cold-mass/string connection

4. **Alignment Area** (AL-WS1, AL-WS2)
   - Cavity and quadrupole fine alignment (~100 µm)
   - Welding of 8 mm LHe filling line (x9)
   - Tuner and piezo electric tests

5. **Cantilever Area** (CA-WS1)
   - Welding of 4K and 70 K shields, 4K and 79 K super insulation
   - Cable routing and insulation, Quad current lead
   - Insertion into vacuum vessel and cold mass alignment

6. **Coupler Area** (CO-WS1, CO-WS2)
   - Warm couplers + coupler pumping line + leak checks (8 connections + coupler vacuum)
   - Cabling of flanges A (x8) and flange D
   - Quadrupole current lead connections and welding
   - Final leak check of cavity vacuum + final pumping

7. **Shipment Area** (SH-WS1, SH-WS2)
   - Control operations (RF frequency)
   - End-caps closing, N₂-insulation
   - CEA-Alsyom “acceptance test”
   - Loading
XM4 (String assembly) on 14/02/2014
Progress Report

XM2 (Alignment) and XM3 (Roll-out) on 14/02/2014
Progress Report

XM1 (Cantilever) on 14/02/2014
Progress Report

XM-1 (Warm couplers) on 14/02/2014
XM1 (Cantilever) and XM-1 (Warm couplers) on 14/02/2014
Progress Report
Back-up Slides: Organisation
CEA Organisation

Experts:
- Survey (M. Fontaine)
- RF (C. Simon)
- Vacuum (C. Boulch)
- Mechanics (J.-L. Perrin)

Project Leader (O. Napoly)

Quality Engineer (C. Cloué)

System Engineer (C. Madec)

Fabrication Manager (T. Trublet)

ALSYOM

Assembly Halls Area Manager (JP. Charrier / C. Madec)

Clean Rooms Area Manager (S. Berry / B. Visentin)

Workshop manager

5 November 2014

O. Napoly, XFEL MAC
Industrial Contract: ALSYOM Management Plan and Staffing

Executive VP

Program Manager
1

Industrial Director

Program Unit Manager in Production
1

Stock and Production Controller
1

Method Expert
1

Stock / Warehouseman
2

Workshop Manager
1

Operators and technicians for the assembly
24

Quality Manager

Quality Engineer / Cleanliness
1

Quality controllers
2

Off site

On site:
33 persons
Industrial Contract: ALSYOM Staffing

Alsyom Staff Evolution
(2 welders subcontracted to SIEV-Energy not included)

- 31/12/2013, 18 persons
- 02/09/2013, 11 persons
- 25/04/2014, 28 persons

Project Weeks

2012 2013 2014