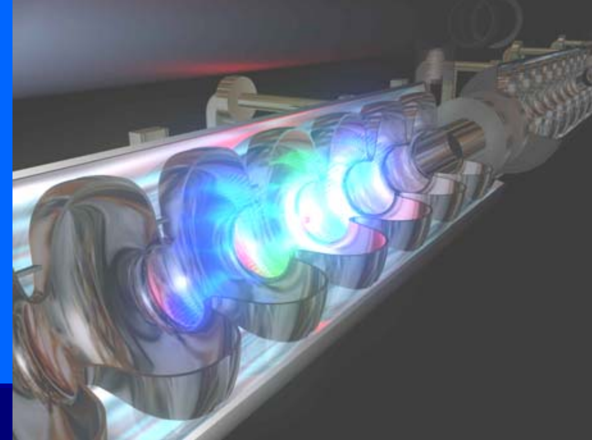
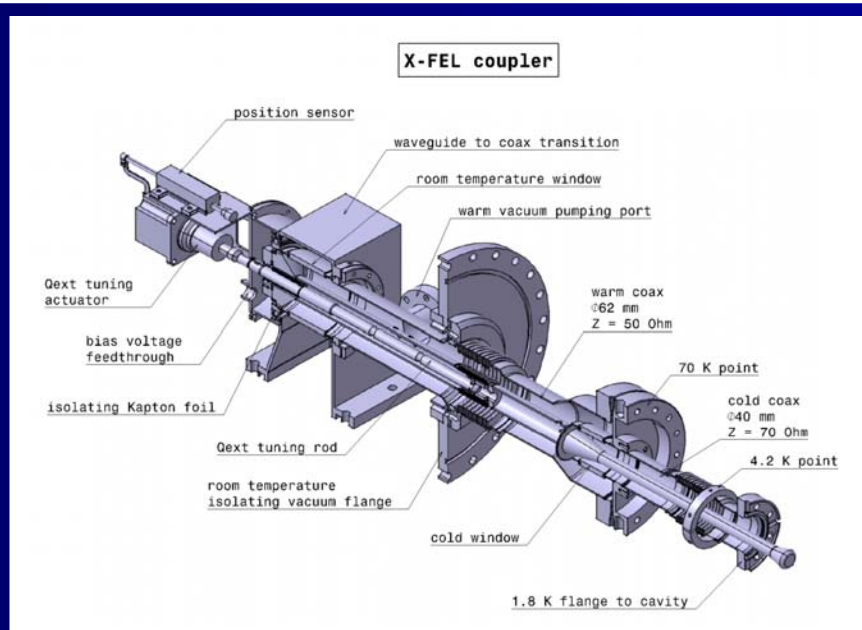
Industrialization process for XFEL Power couplers and Volume manufacturing

TTC meeting at Fermi lab, April 2007

Serge Prat / LAL - Orsay





Scope of delivery

Manufacturing parts and sub-assemblies

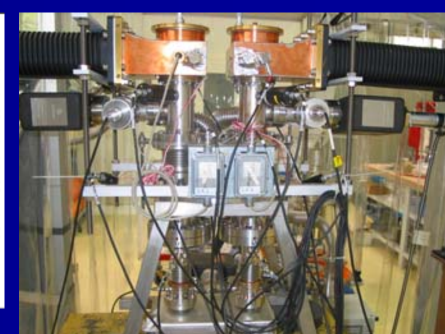
In ISO 6 and ISO 4 clean room:

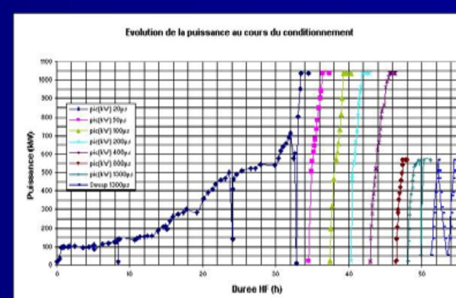
- Cleaning
- pre-assembly
- Vacuum oven outgassing
- Final assembly on test stand

Final assembly

1 000 couplers are needed for XFEL

- Vacuum pumping
- In situ baking
- Connect to RF power





RF conditioning

- Dismount
- Pack
- Transport

Deliver 2 by 2

Expertise required from industry

EB welding

Vacuum brazing

TiN coating

Geometrical tolerances

Surface finish
and cleanliness

TIG welding

Cu plating

Motorized tuning

EN 1.4435

EN 1.4429

Special austenitic stainless steel

+ Handling with gloves
+ Assembly in clean room
+ RF Conditioning

Industrialization studies: Why ?

Start with: Prototypes

(40 Couplers)

Quality:
- uneven
- NC, several anomalies

Manufacturing:
- long and difficult
- lack of procedure
- only a few people have the competence

High cost

Industrialization process

End objective: Large series

XFEL: 1 000 Couplers

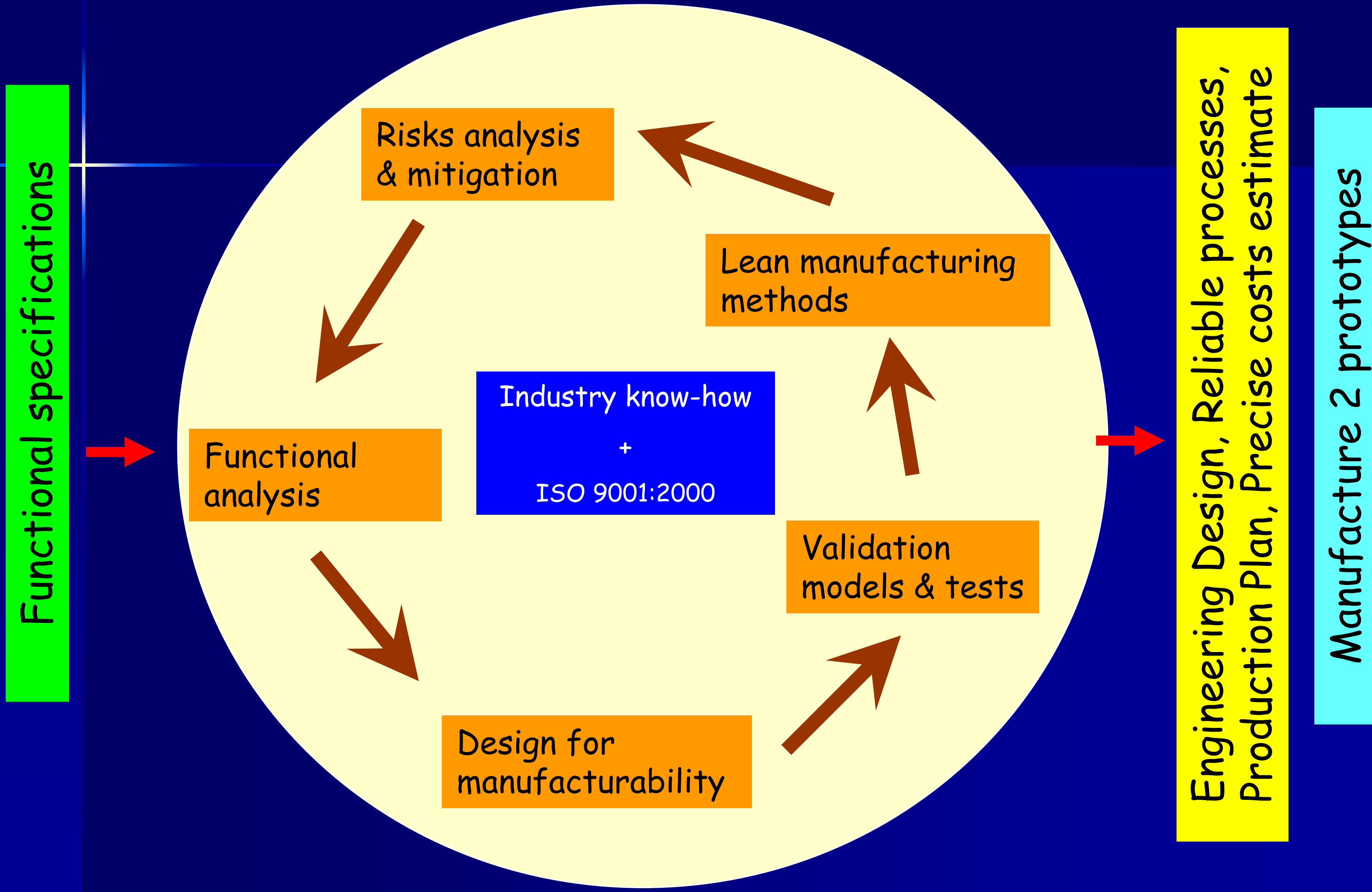
ILC: 20 000 Couplers

Quality:
- equal for all items
- reliable

Manufacturing:
- regular process
- written procedures
- standard competence

Lower cost:
- 60% cost decrease

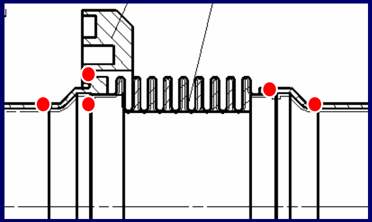
Industrialization studies: Working process



Some results

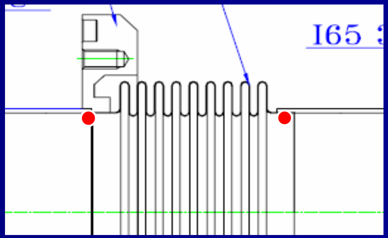
- Functional analysis
  - Small thermal emissivity coefficient → Polish the antenna (gain in radiative thermal power)
  - Thermal model → Cu rings at 4K point can be attached on thicker tube instead of bellows, brazed or glued
  - Big flange on vacuum vessel: 12 holes are enough instead of 24
  - Change some materials in actuator for radiation resistance
  - Choose PPS for connectors and Kapton for cable insulation
  - Floating big flanges must be supported

- Design for manufacturability
  - Choose deformation techniques instead of machining: *deep drawing, spinning, pull-out*
  - Optimize the process for vacuum brazing by use of special tooling: *adapt tolerances & thermal expansion*
  - Decrease number of parts and junctions:

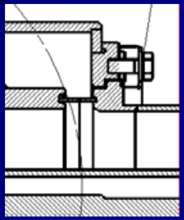


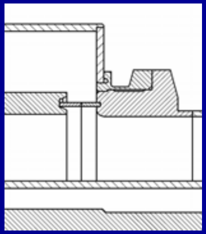
6 Parts 4

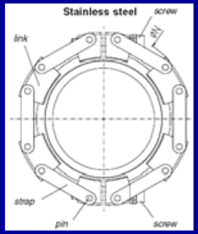
5 Junctions 2



- Lean manufacturing
  - Use RF seals for better electrical contact at waveguide interface box
  - Use chain clamp instead of screws for assembly







Materials for motorized actuator

Materials damaged by 1 MGy radiation dose

No data for these materials

Actuator Materials List

Description	Base Material	Coating	Additional Material
front endbell	aluminum	Electrophoresis Coating	
rear endbell	aluminum	Electrophoresis Coating	
ball bearing	52100 chrome steel		Chevron SRI2 lubricant
linear insert	brass		
linear nut	30% glass filled polyester		
magnet	sintered BdFeB	Electrophoresis Coating	
rotor stack	silicon steel lamination		aluminum rivet
spring washer	carbon steel		
spanner nut	aluminum	black anodize	
e-ring	spring steel	black phosphate	
captive sleeve	aluminum	black anodize	
molded sleeve	30% glass filled polybutylene terephthalate (PBT)		
end stop	303 stainless steel		
pinion	303 stainless steel		
assembly screw	mild steel	zinc plated	
stator stack	silicon steel lamination		
front stator insulator	Nylon 6		
rear stator insulator	Nylon 6		
lead wire	tin plated copper	polyelethylene insulation	
magnet wire	copper	polyurethane/polyamide	
solder	pure tin solder, resin core 66 flux		
label	mylar		Flexcon V-23 adhesive
rust inhibitor	LPS 3 heavy duty rust inhibitor		
grease	Perfluoropolyether grease		
threadlocker	Loctite 272		
adhesive	Loctite 496		
adhesive	Loctite E-214HP		

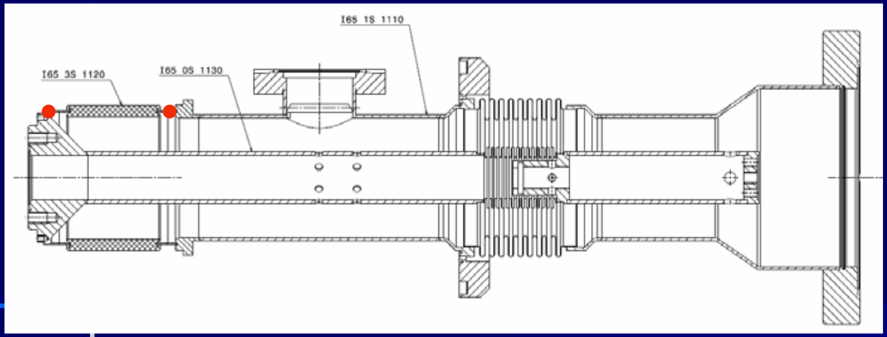
Materials for motorized actuator

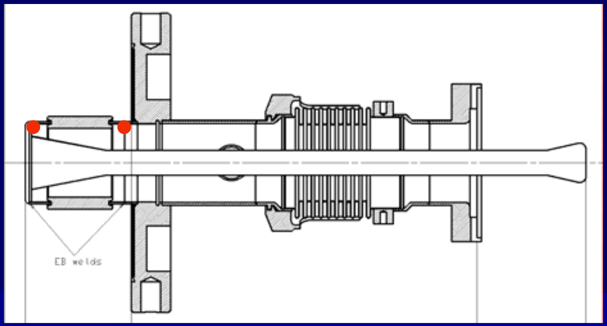
New Materials proposed for 1 MGy radiation dose:

→ Tooling cost ~ 7000 $

Description	Base Material	Coating	Additional Material
front endbell	aluminum	Electrophoresis Coating	
rear endbell	aluminum	Electrophoresis Coating	
ball bearing	52100 chrome steel		Mineral oil lubricant
linear insert	brass		
linear nut	30% glass filled polyester		
magnet	sintered BdFeB	Electrophoresis Coating	
rotor stack	silicon steel lamination		aluminum rivet
spring washer	carbon steel		
spanner nut	aluminum	black anodize	
e-ring	spring steel	black phosphate	
captive sleeve	aluminum	black anodize	
molded sleeve	Glass filled polyester (tooling $$)		
end stop	303 stainless steel		
pinion	303 stainless steel		
assembly screw	mild steel	zinc plated	
stator stack	silicon steel lamination		
front stator insulator	Glass filled polyester (tooling $$)		
rear stator insulator	Glass filled polyester (tooling $$)		
lead wire	tin plated copper	polyimide insulation	
magnet wire	copper	polyimide insulation	
solder	pure tin solder, resin core 66 flux		
label	Remove label: stamp mounting plate		No adhesive
rust inhibitor	LPS 3 heavy duty rust inhibitor		
grease	Apiezon L grease		
threadlocker	Loctite 638		
adhesive	Loctite 638		
adhesive	Loctite E-214HP: this is an epoxy resin		

Joining techniques





- **Proposal 1**
  - Joining done as for TTF3 couplers baseline:
    - Stainless steel parts: TIG welds
    - Cu to stainless, Cu to ceramics: vacuum brazing
    - Final joints by EB-weld

- **Proposal 2**
  - Final assembly by TIG welding:
    - Stainless steel parts: TIG welds
    - Cu to stainless, Cu to ceramics: vacuum brazing
    - Final joints by TIG weld

- **Proposal 3**
  - All metallic joints are brazed under vacuum:
    - Brazing to bellows → problem of annealing bellows
    - Cu to ceramics: vacuum brazing
    - Final joints by brazing → problem of Ti diffusion into ceramic

Cu coating

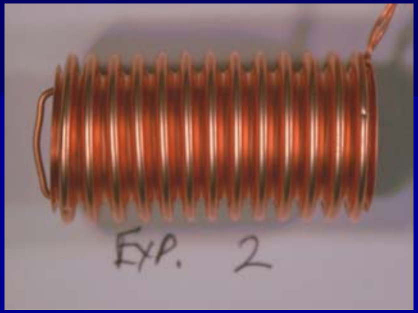
- Different processes are proposed for electroplating:
    - DC current
    - pulsed current power supply

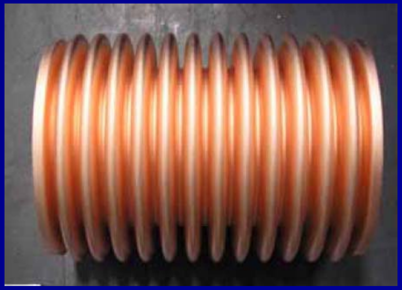
- Different bath types are investigated:
    - acid bath
    - cyanide bath
    - sulfate bath
    - pyrophosphate bath

- samples received by LAL to measure RRR

  Before baking: RRR = 22

  After baking 2h at 400°C : RRR = 63



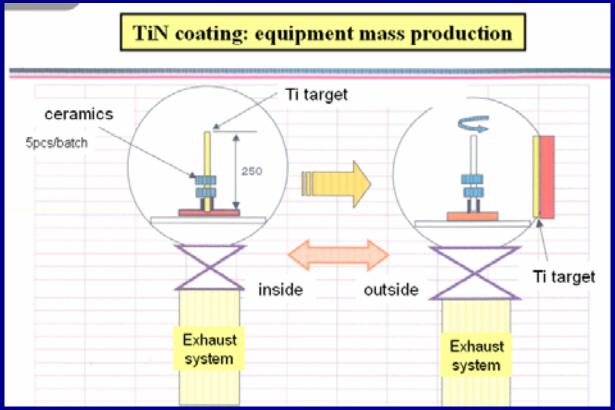


TiN coating

→ 2 different processes are proposed:

→ vacuum evaporation techniques using equipment of same design as at DESY
- deposit of Ti, then transformation into TiN by introduction of NH3 gas
- or direct deposit of TiN: evaporation of Ti in N2 atmosphere

→ sputtering process: under N2+Ar pressure



→ Equipment are being assembled, 1st tests soon

Validation samples and tests

→ Manufacturing techniques:

- tube pull out for e- pickup and pumping ports
- deep drawing for conical part

→ TIG welding:

- Validate TIG welds from outside

→ Vacuum brazing:

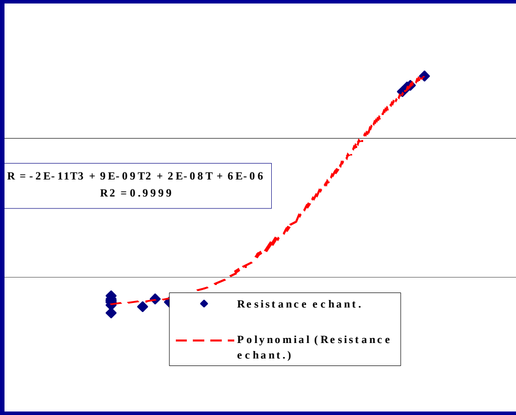
- He leak test < 10^{-10} Pa m^3/s
- pull tests on window assembly

OK if

σ_m > 100 MPa

→ Cu coating:

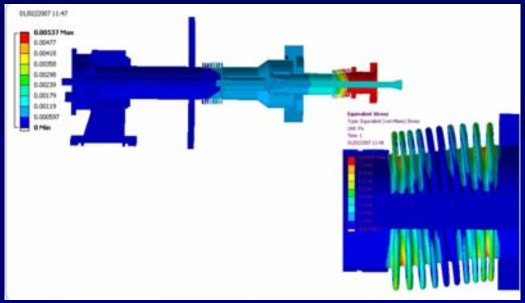
- adhesion test
- thickness uniformity measurements on bellows
- RRR measurements

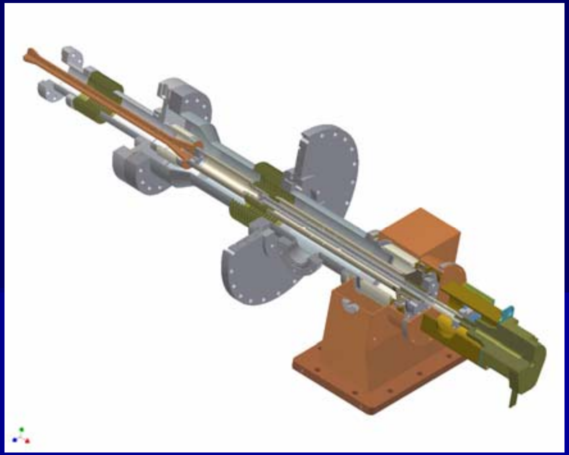


→ TiN coating:

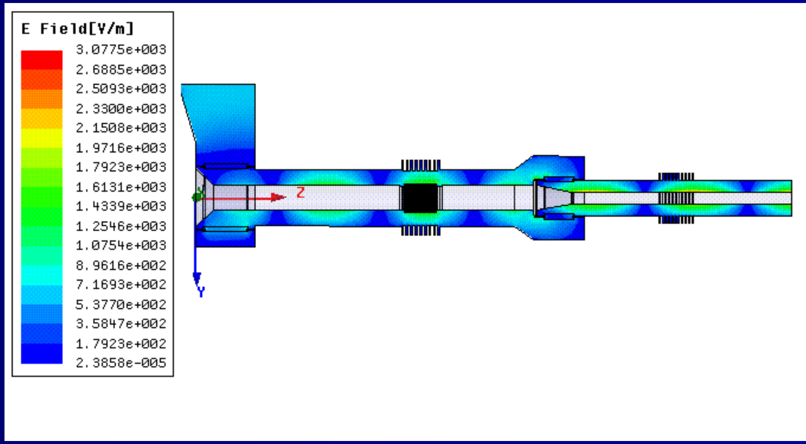
- layer thickness and stoichiometry
- ε_R and tanδ measurements on ceramic

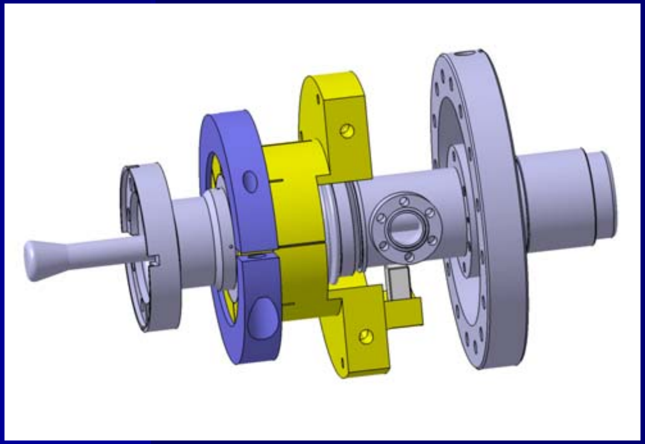
Some work results



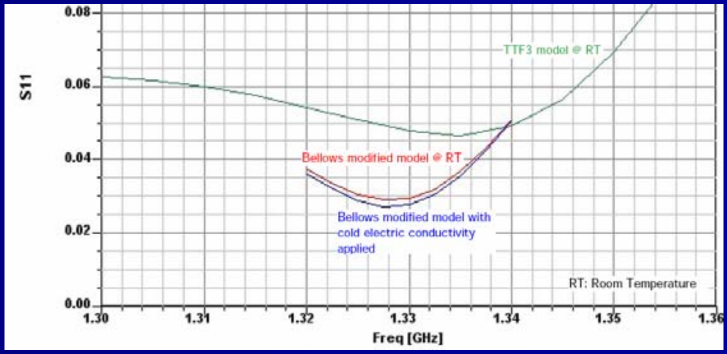


Warm window sample





Sliding support



Project Reviews for industrial studies

1 - System Design Review

- → Make sure that:
  - requirements are well understood
  - efforts are in the right direction
  - the industry puts the right amount of resources
  - the schedule is controlled
- → Finalize Technical specifications
- → Identify the problems
- → Evaluate the feasibility of proposed solutions

2 - Preliminary Design Review

- Demonstrate the compatibility of the proposed design with the original needs
- Explain how the mass production will be managed, organized, controlled
- Prove the feasibility of manufacturing processes and sequences
- Deliver models and samples for joining, materials, manufacturing techniques, Cu coating

➢ 3 - Critical Design Review

- Provide final Validation samples of Cu plating and TiN coating

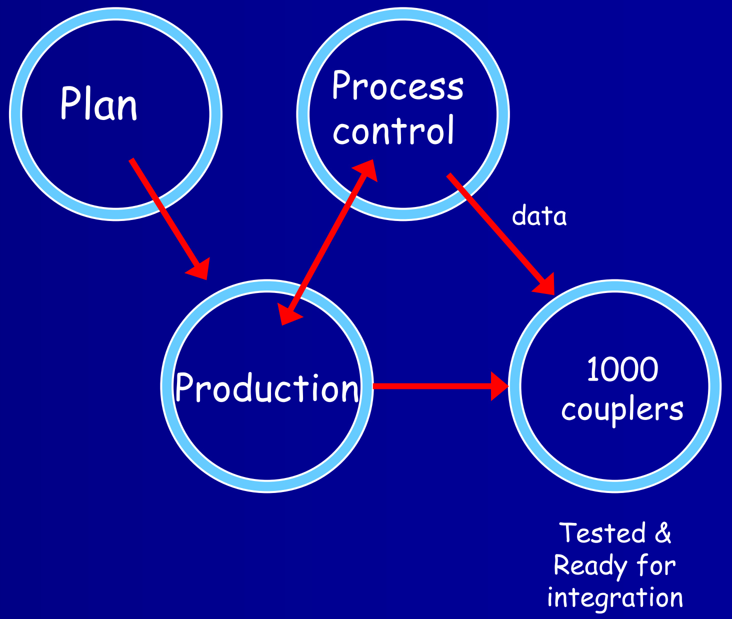
- Finalize PBS, WBS and all processes for volume manufacturing
- Establish detailed drawings and bill of materials
- Manufacturing plan for 2 prototypes

- Update the Assembly plan for volume production
- Clean room layout and equipment

- Quality Control Plan for volume manufacturing

➢ **Objective:**

SMART COUPLER FACTORY

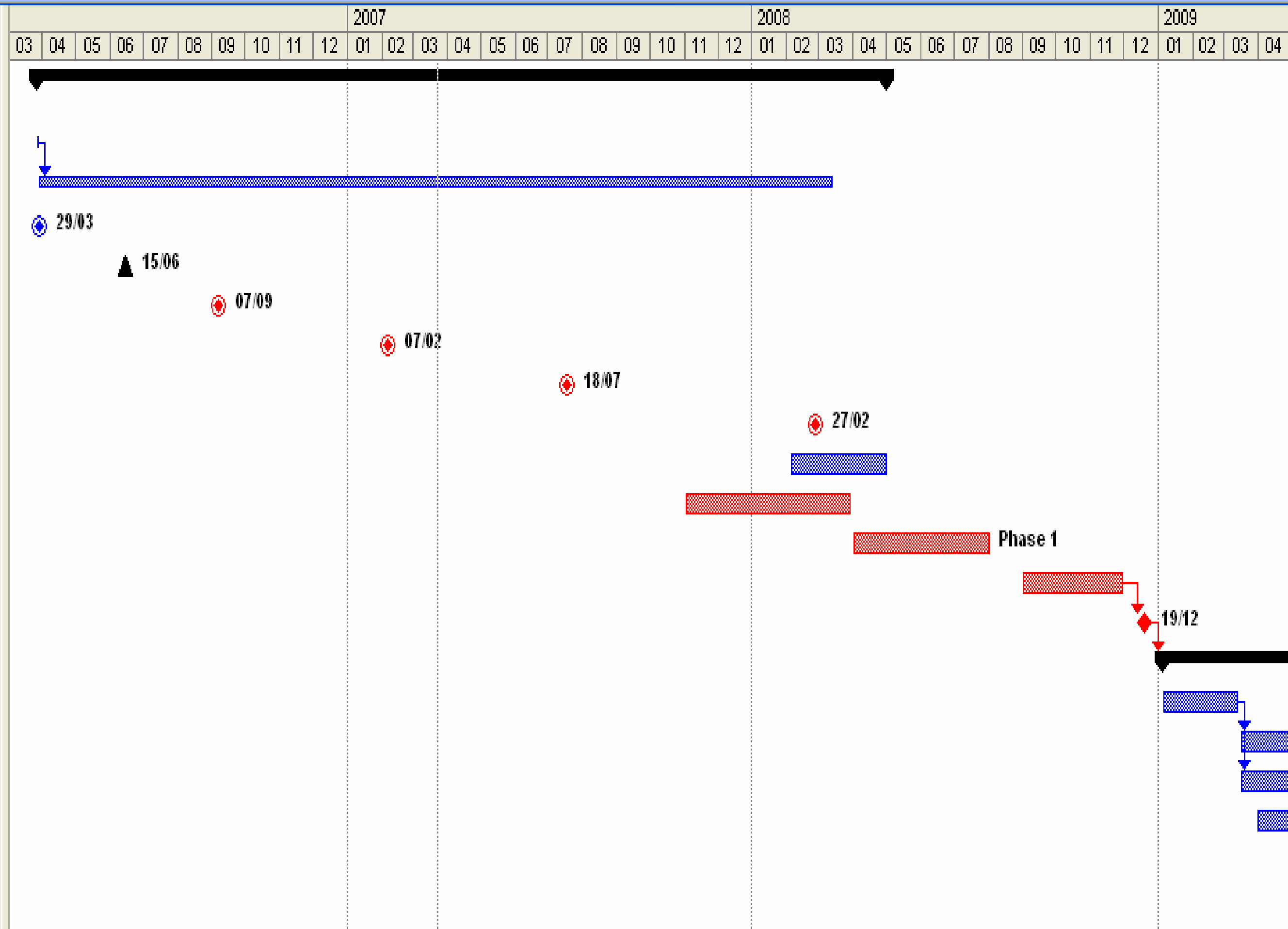


➢ 4 - Final Review

- Deliver 2 prototypes with control data
- Volume manufacturing plan
- Configuration control plan
- Final risks analysis
- Cost estimate for XFEL couplers
  - ➢ fixed costs
  - ➢ recurrent costs
  - ➢ large equipment costs

Schedule of « Industrialization studies »

	Nom de la tâche	Début	Fin
1	**Industrialization studies**	**27/03/06**	**30/04/08**
2	Award of 3 definition contracts	27/03/06	27/03/06
3	Progress of 3 definition contracts	28/03/06	12/03/08
4	Kick-off Review	29/03/06	29/03/06
5	Development plan delivery	15/06/06	15/06/06
6	System Design Review	07/09/06	07/09/06
7	Preliminary Design Review	07/02/07	07/02/07
8	Critical Design Review	18/07/07	18/07/07
9	Final Review and delivery of prototypes	27/02/08	27/02/08
10	Evaluation of prototypes	04/02/08	30/04/08
11	Writing specifications and documents for CFT	01/11/07	28/03/08
12	Publish Call for Tenders	01/04/08	31/07/08
13	Negociation Process	01/09/08	28/11/08
14	Award of manufacturing contract(s)	19/12/08	19/12/08
15	**XFEL couplers manufacturing phase**	**05/01/09**	**30/12/11**
16	Manufacturing plan development	05/01/09	13/03/09
17	Logistics and equipment	16/03/09	20/11/09
18	Material procurement	16/03/09	02/09/11
19	Prototypes and pre-series manufacturing	31/03/09	30/09/09
20	Manufacturing in series	01/10/09	16/12/11
21	**Delivery of 25 series of 40 couplers**	**30/12/09**	**30/12/11**



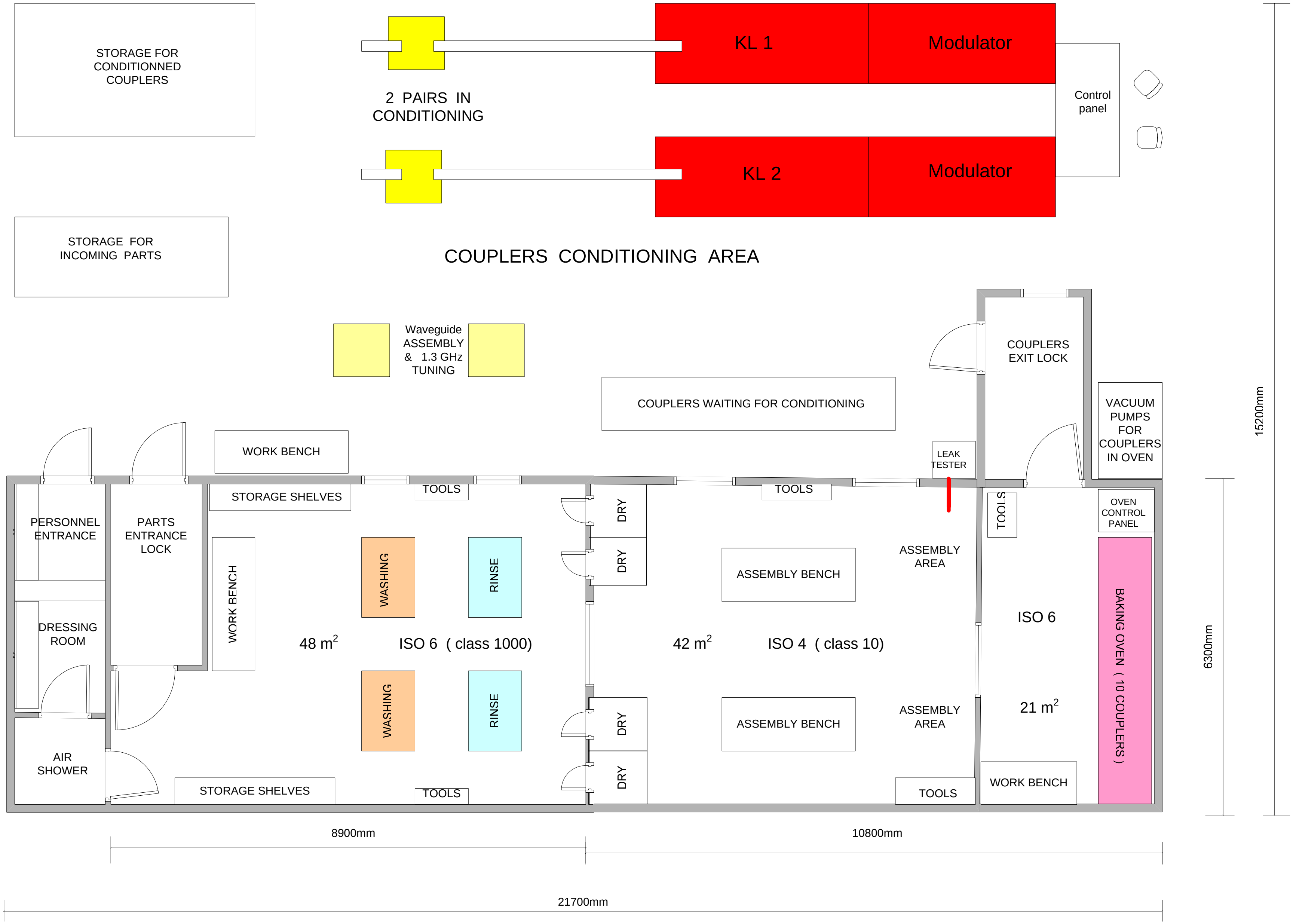
Contract(s) for manufacturing the 1000 power couplers for XFEL will be awarded in 2008

→ Call for tenders for production of XFEL couplers will be initiated mid 2008, based on functional specifications

→ Negociation procedure: both on technical content and on price

Evaluation of tenders will include:

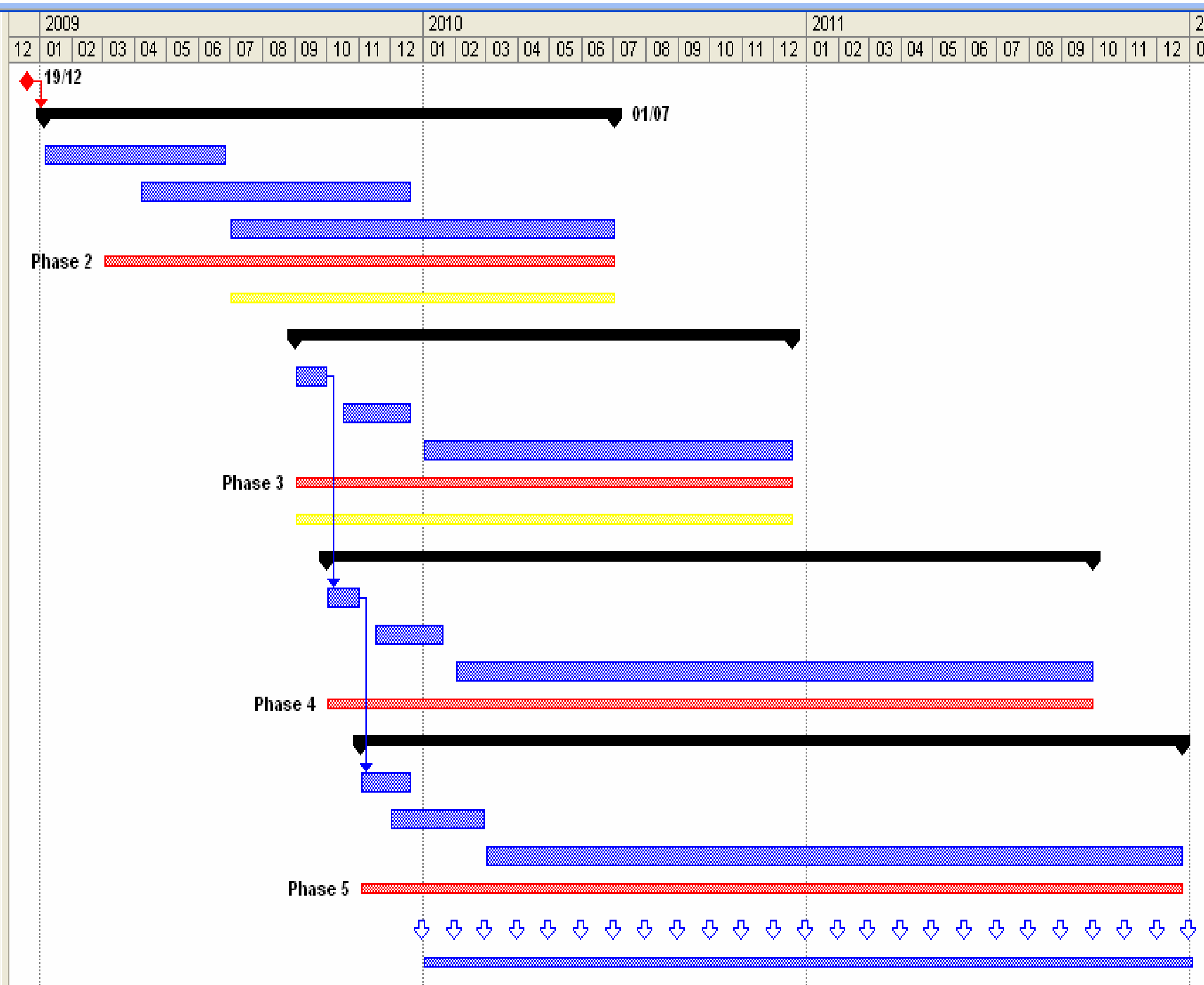
- Technical content
- Production schedule
- Price
- Technical audit of candidates:
    - Expertise in the domain
    - Previous experience with couplers
    - Manpower and equipment
    - Logistics
    - QA audit wrt ISO 9001:2000
- Risks analysis: technical & financial



CLEAN ROOM FOR XFEL COUPLERS ASSEMBLY (1 PAIR / DAY)

Schedule of « Production of Power couplers for XFEL »

	Nom de la tâche	Début	Fin
1	Award of manufacturing contract(s)	19/12/08	19/12/08
2	**⊟ XFEL couplers manufacturing phase**	**05/01/09**	**01/07/10**
3	Project organization and engineering	05/01/09	26/06/09
4	Material procurement and part production	06/04/09	18/12/09
5	Manufacturing of sub-assemblies	01/07/09	01/07/10
6	Manufacturing Follow-up by LAL	02/03/09	01/07/10
7	Joining control by external inspector	01/07/09	01/07/10
8	**⊟ Cu coating and final weld**	**01/09/09**	**17/12/10**
9	2 series of 20 couplers	01/09/09	30/09/09
10	2 series of 40 couplers	15/10/09	18/12/09
11	22 series of 40 couplers	01/01/10	17/12/10
12	Follow-up by LAL	01/09/09	17/12/10
13	Production control by external inspector	01/09/09	17/12/10
14	**⊟ Cleaning, Assembly & Baking**	**01/10/09**	**30/09/11**
15	2 series of 20 couplers	01/10/09	30/10/09
16	2 series of 40 couplers	16/11/09	18/01/10
17	22 series of 40 couplers	01/02/10	30/09/11
18	Assembly control by LAL	01/10/09	30/09/11
19	**⊟ Conditioning, shipping and delivery**	**02/11/09**	**23/12/11**
20	2 series of 20 couplers	02/11/09	18/12/09
21	2 series of 40 couplers	01/12/09	26/02/10
22	22 series of 40 couplers	01/03/10	23/12/11
23	Conditioning control by LAL	02/11/09	23/12/11
24	**⊞ Delivery of 25 series of 40 couplers**	**30/12/09**	**30/12/11**
50	Acceptance tests + storage	01/01/10	02/01/12



Industry follow-up tasks to be done by LAL

Phase 2: Manufacturing of parts and sub-assemblies

At LAL

- Check project organization at industry
- verify manufacturing drawings
- control procurements: raw material, subcontractors
- check manufacturing plan
- check joining processes (welding, brazing)

\+

- Quality parameters control
- schedule control
- documents control
- collect data and watch drift
- invoices control
- report to XFEL project group

At Industry

- control manufacturing process: Witness points, Hold points
- collect data
- Project reviews

Phase 3: Cu + TiN coating and final joining

At LAL

- RRR measurements on samples
- test final joining on samples

At Industry

- control Cu coating process parameters
- control final joining process: H points
- collect data

2 options are envisaged for phases 4 & 5

Option A

Ind 1 → Ind 1

Ind 2 → Ind 2

Phase 3

Cleaning, assembly, conditioning

- Acceptance tests
- Dismount
- Return packing + supports

DESY → XFEL

- Storage
- assemble on modules

Option A

Option B

Ind 1

Ind 2

Phase 3

simple shipping containers

- Sub-assemblies storage
- Cleaning, assembly, conditioning

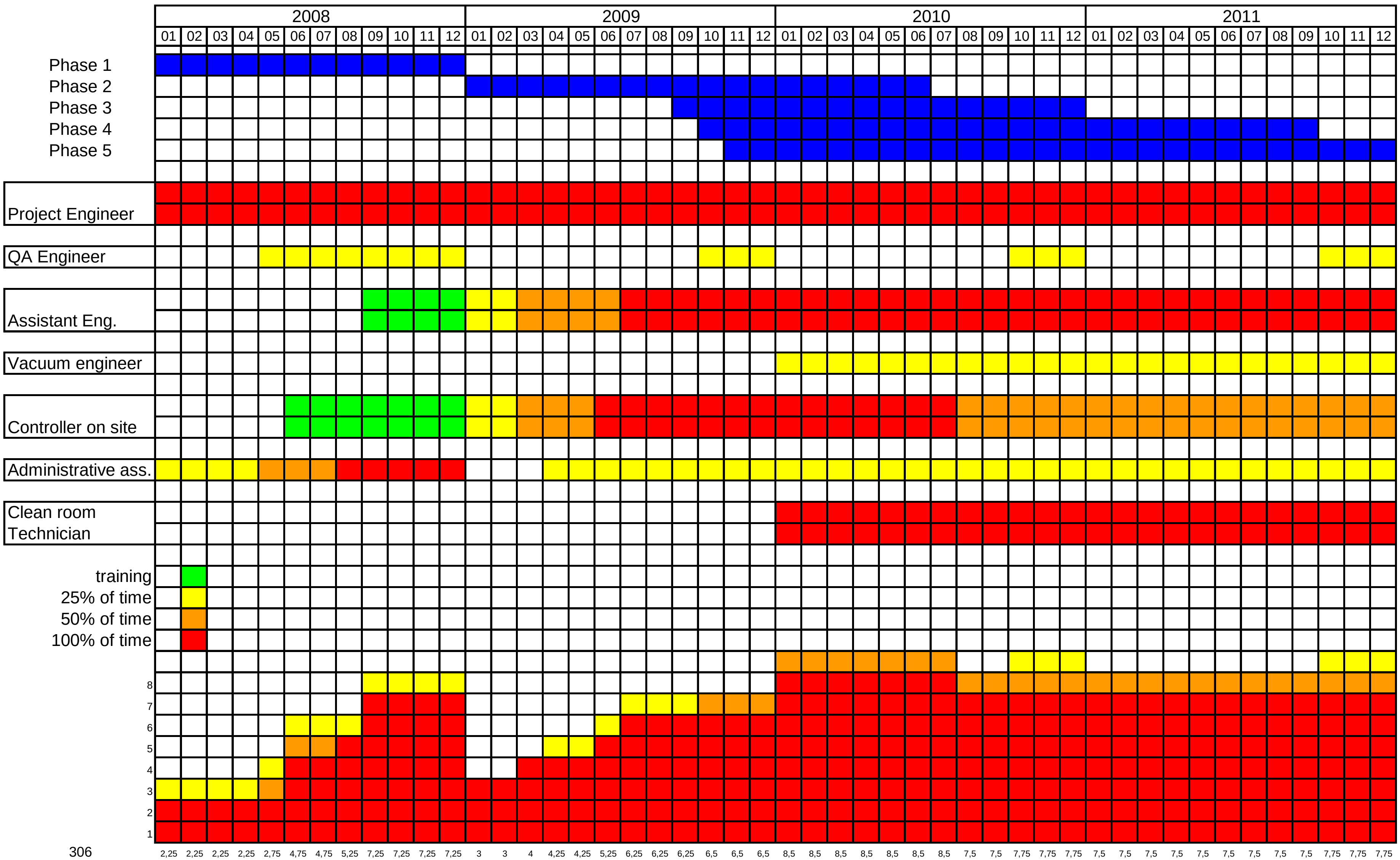
Single location

- Acceptance tests
- Dismount
- Storage
- assemble on modules

XFEL

Option B

Personnel resources (LAL) for XFEL power couplers project



FTE : 306 / 12 = 25,5 man x year