

Experience with Couplers Production and Outlook for ILC

Florian GESLIN (THALES, France)



- **Introduction**
- **Thales/MIS presentation**
- **European-XFEL/LCLS-II Coupler description**
 - Manufacturing
 - Cleaning
 - RF conditioning
- **Lessons learned**
- **Improvement for serial production**

Over **80,000**
employees 

68 
Countries
Global presence

1 bn € 
Self-funded R&D*

* Does not include externally financed R&D

Sales in 2018 
19 bn €

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MIS | Our business line within THALES Group



Digital Identity and Security



Defense and Security



Aerospace



Space



Ground Transportation

Flight Avionics
In-Flight Experience
Electrical Systems
Training & Simulation

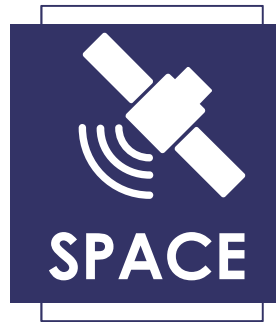
**MICROWAVE & IMAGING SUB-SYSTEMS
(MIS)**

« We help customers master decisive moments by providing the right information at the right moment »

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THALES

3 Business Segments



OPEN

DEFSI



N°1 WORLDWIDE

for industrial amplification

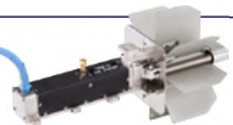
N°1 EUROPE

for scientific and defence tubes

LONG STANDING PARTNER

with the most prestigious research centres and laboratories

SPACE



N°1 WORLDWIDE

for space amplification

PRODUCTION CAPACITY

1 800 tubes per year

ORBITAL OPERATION

860 million cumulated hours

TUBES IN ORBIT

17 000

RAD



A WORLDWIDE LEADER

for radiological analog and digital imaging

PRODUCTION CAPACITY

OVER 15 000

detectors per year

50% OF ALL

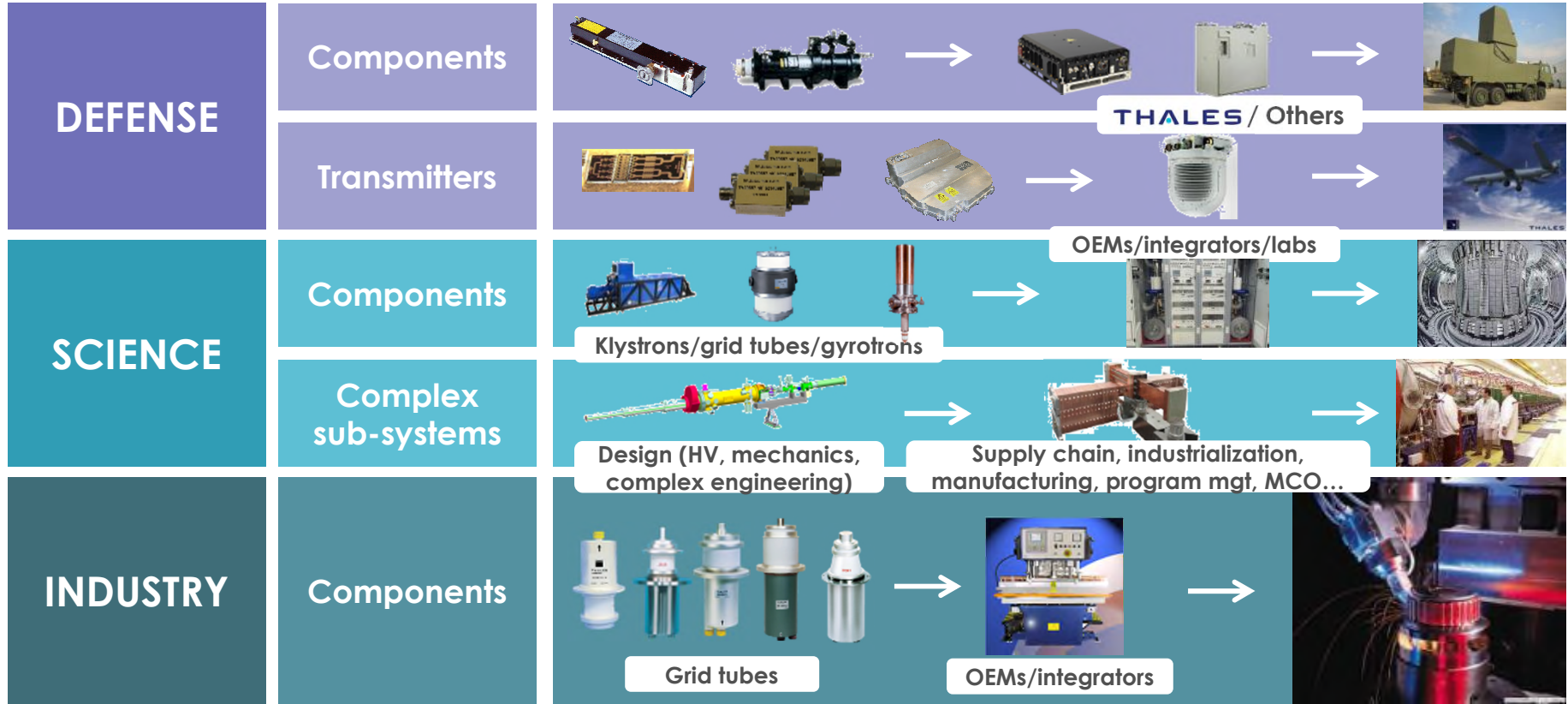
X-ray exams worldwide use a Thales detector

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THALES

MIS | DEFSI Product Lines

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THALES / Others

OEMs/integrators/labs

Klystrons/grid tubes/gyrotrons

Design (HV, mechanics, complex engineering)

Supply chain, industrialization, manufacturing, program mgt, MCO...

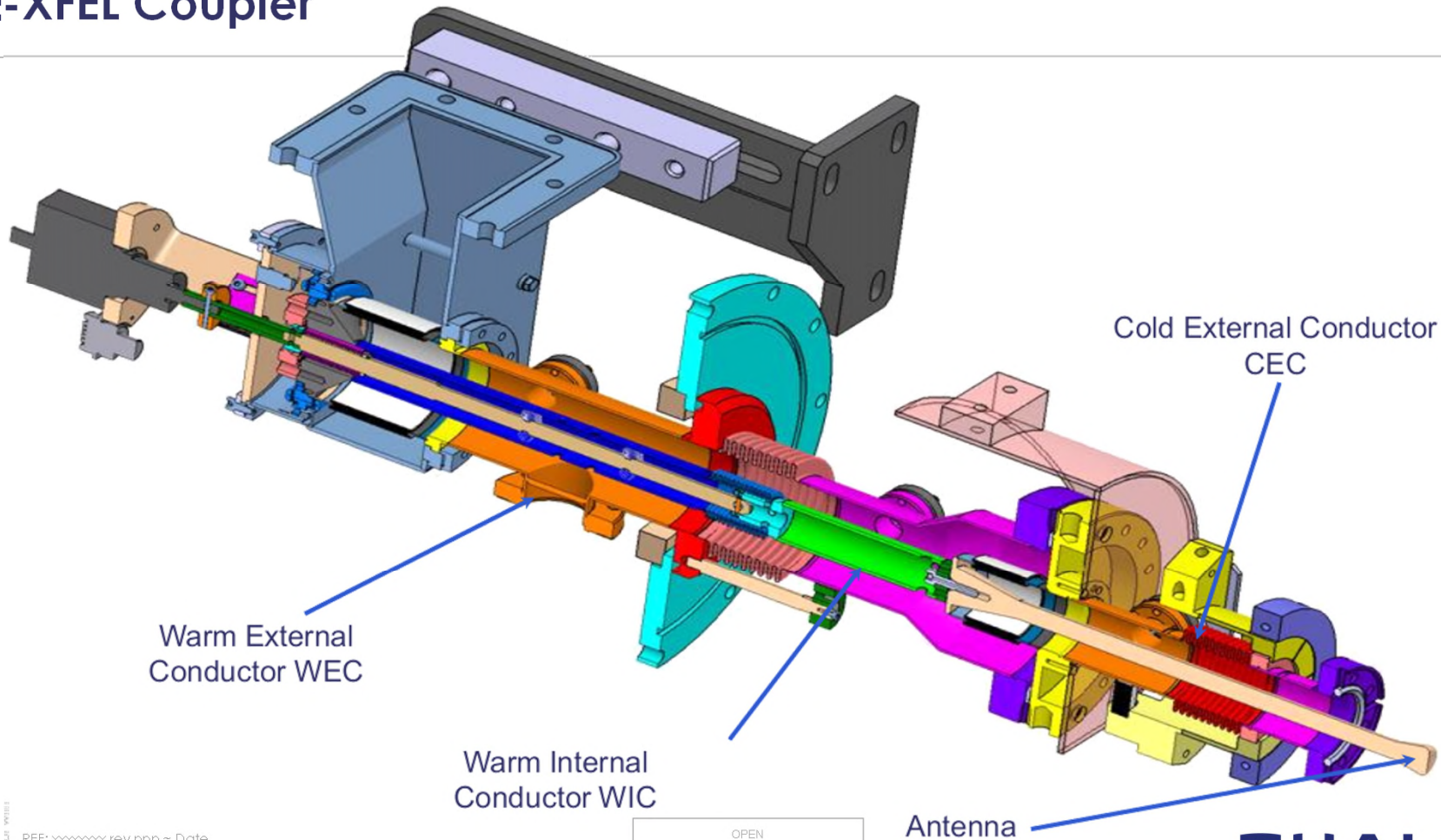
Grid tubes

OEMs/integrators

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E-XFEL Coupler



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European-XFEL, LCLS II main differences:

	E-XFEL	LCLS II
Copper coating on WIC	30µm	150µm
Profile of the antenna	X	X
Tuning by motor	Yes	No
RF power conditioning	Up to 1MW	No

Manufacturing steps

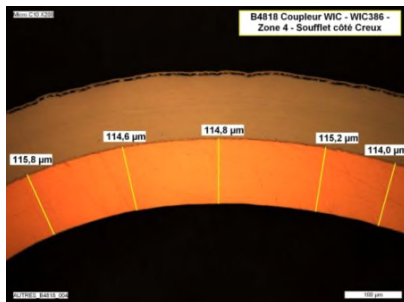
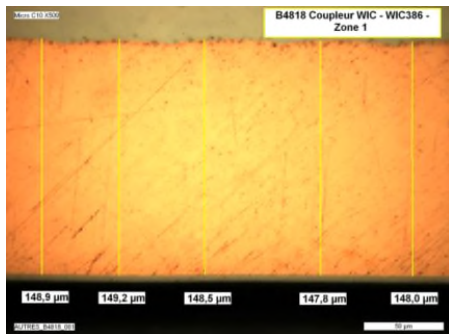
- Thales and RI in consortium for the manufacturing of couplers
- E-XFEL: LAL for the RF conditioning before shipping

	Thales	RI
Main subassemblies	Antenna, WIC, WEC, CEC	Ceramic windows
Processes	Copper coating	TiN coating and final EBW
	LAL	
	X-FEL	LCLS II
Auto. RF Conditioning	yes	No
RF power conditioning	Up to 1 MW	no

Manufacturing flowchart

- At Thales site: Brazing of the inner and outer conductors.
- At Thales site: Copper plating of the inner surfaces.
- At Thales site: Inspection & control of all the produced.
- Delivery to RI with double check at reception at RI site under the same shared inspection criteria.
- At RI : TiN coating of ceramics
- At RI : EBW of cold part: ceramics with antenna and Cold External Conductor
- At RI : EBW of Warm Part: ceramic with Warm external and Warm internal conductor
- At RI : Degreasing and assembly of couplers
- At RI : Delivery to LAL

- A lot of controls are done on sub assemblies and final couplers
- Non destructive like dimensional control, vacuum leak tests, thickness of copper coating
- Some destructive controls also like for RRR measurements of real pieces, metallographic tests on copper coating

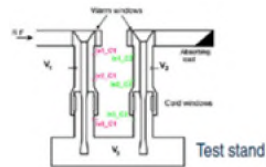
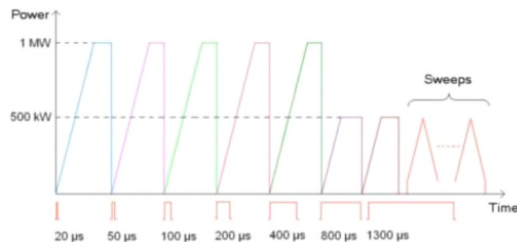


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RF conditioning at LAL for XFEL program

LAL was in charge of the automatic RF conditioning of couplers by pair

Thales and LAL realized the automatic test bank for this RF conditioning

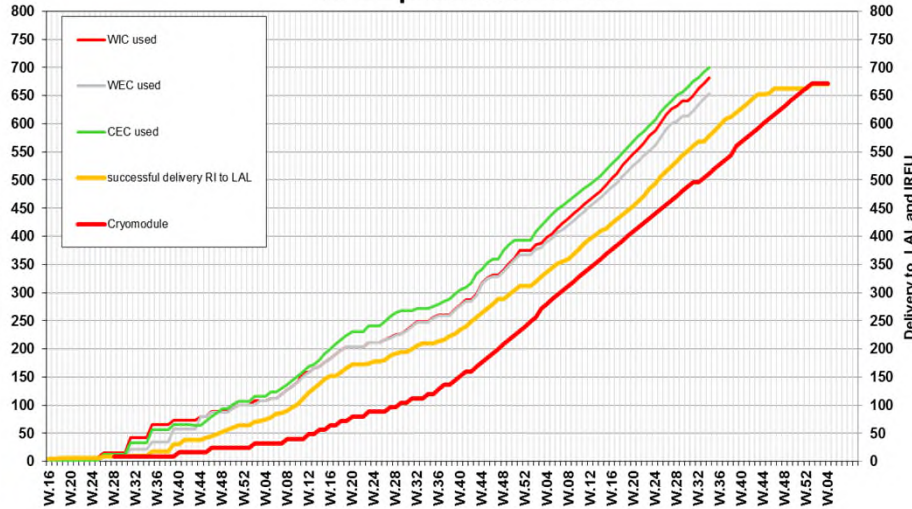


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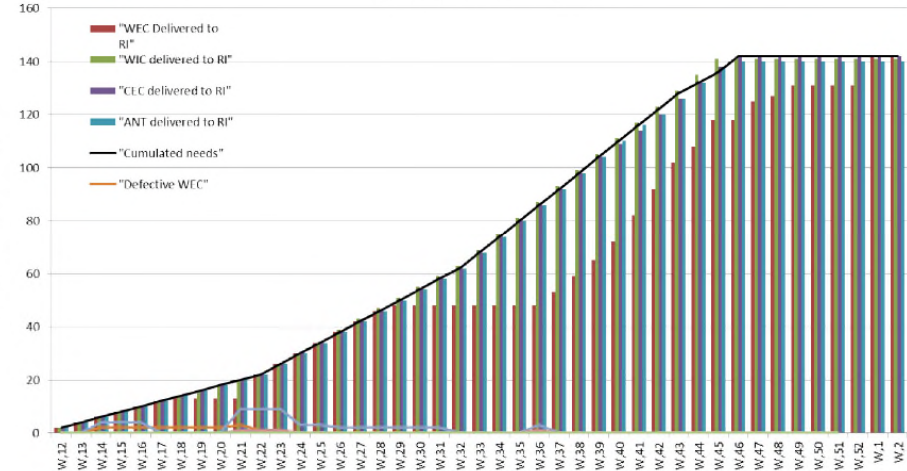
THALES

European XFEL and LCLS II production

XFEL production chart



SLAC production chart



- Thales and RI Research Instruments have demonstrated the capability to have a production rate of 10 couplers a week for the European XFEL accelerator.
- LAL demonstrated the capability to perform automatic RF conditioning of more than 10 couplers a week.

Outlines

- Introduction
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- Improvement for serial production

Lessons learned

■ **With ≈ 1000 couplers manufactured, we have some statistics for parameters and specifications:**

➤ **Among them:**

- **Thickness tolerances**
- **RRR values**
- **Statistics on typical defects**
- **Etc.**

Ramp up and ramp down

Ramp up and Ramp down must be clearly considered and not underestimated.

- Ramp up: we (manufacturers & labs) have to learn on processes and also have a clear and shared vision on criteria for acceptance of pieces
- Ramp down: during the full production phase, defective and “suspicious” pieces are sweep aside but at the end, repair and recovery must be considered (roughly 200 pieces on the E-XFEL program).
- That's true at all stages:
 - Manufacturing of single sub assemblies
 - Assembly of couplers
 - RF conditioning

Difference between perfect and good enough to be used

Perfect:

- Every component is within tolerances and nothing appears on visual inspection but:
 - All criteria are not objective criteria specially visual inspection criteria

Good enough :

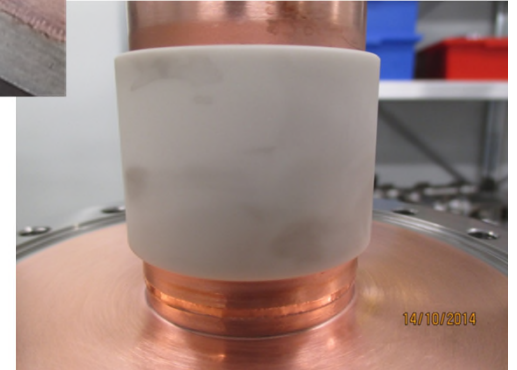
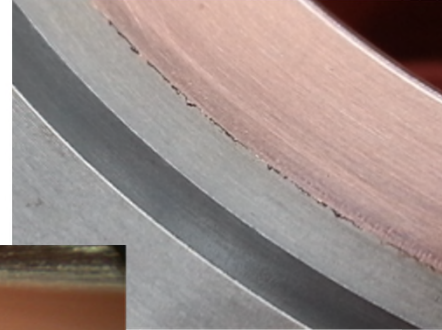
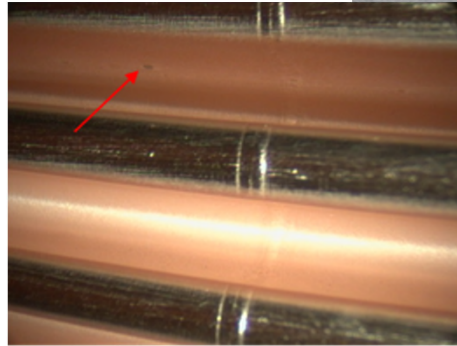
- Define what should be acceptable as “deviations”
- Define what is never acceptable

Examples on visual criteria (next slide)

Example: visual acceptance criteria

Example:

- peeling CF flanges
- Protrusions, pitting, craters...
- Tinted ceramics

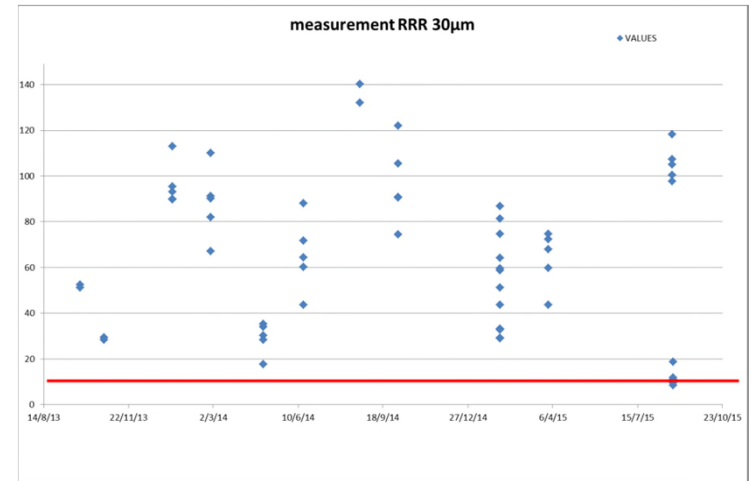
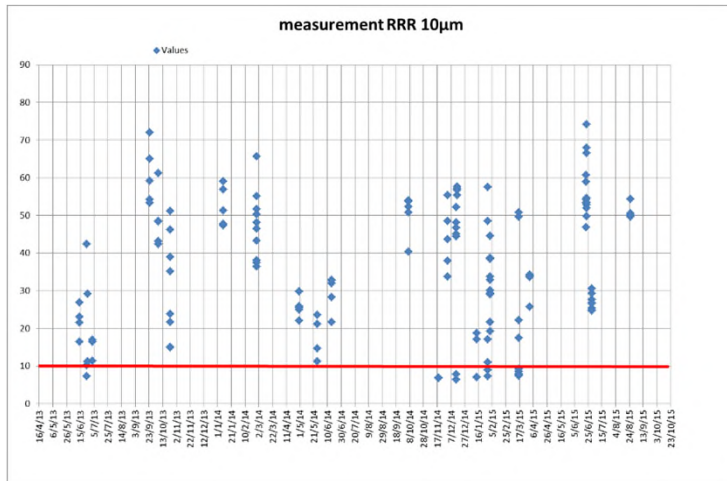


Objective criteria are measurable, clearly defined, with magnification of observation, numbers and size of what is acceptable and what is not acceptable

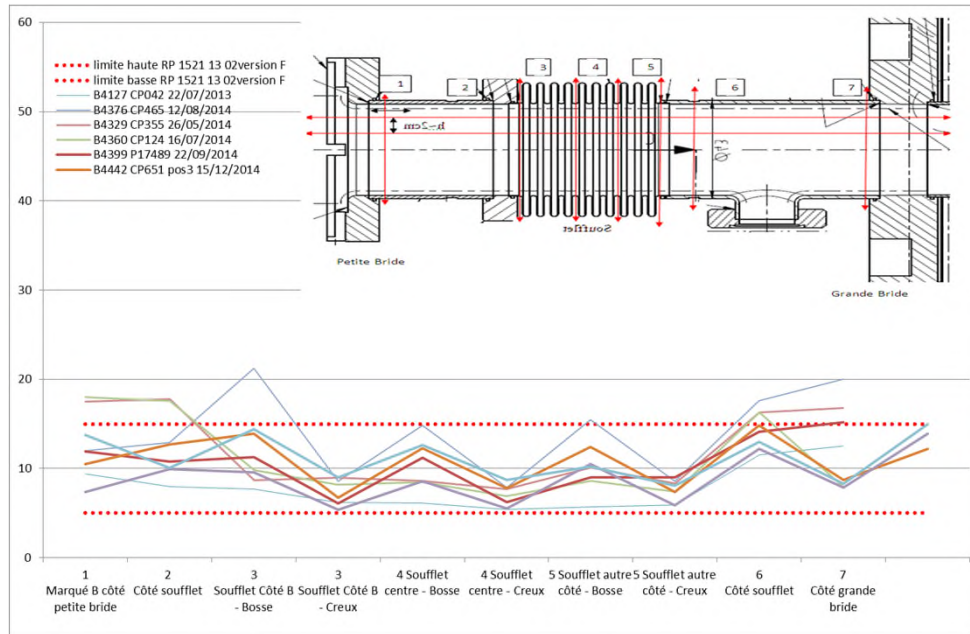
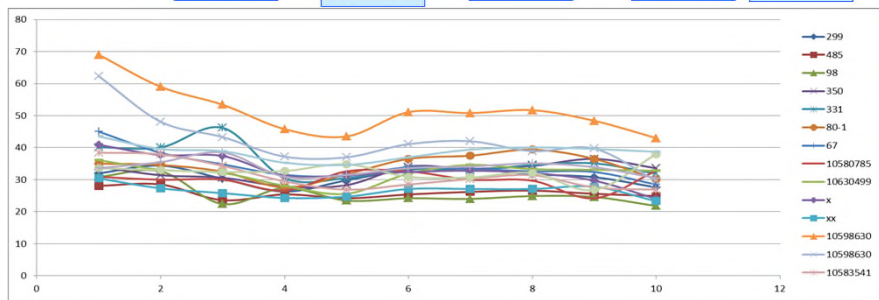
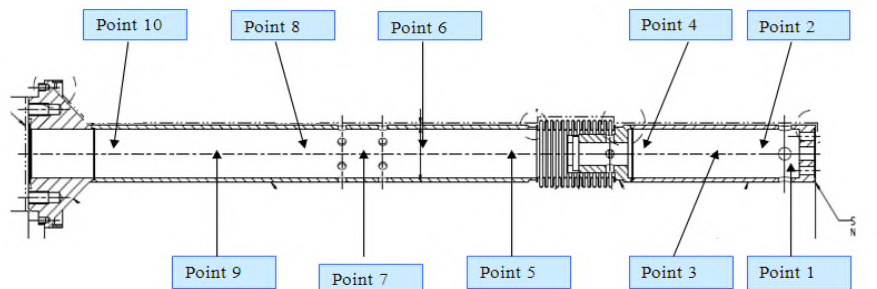
Are all specifications totally well known?

➤ Example on thickness and RRR

- Initial specification: $30 < \text{RRR} < 80$
- Measurements show that a strong dispersion appears on RRR values, measurements done on the same piece and samples independently of any geometrical or bath correlation. Why.?



Tolerances on thickness



Tolerances : questions

- **Should some couplers be rejected because some part are out of specifications on thickness?**
- **Should some couplers be rejected because of RRR dispersion and some values out of specification ?**
 - within same bath, during same phase of coating but with some discrepancy between samples and real different part of pieces

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General rule applied for XFEL/LCLS II manufacturing to be developed for future project:

- Prefer brazing of sub-assemblies , instead of welding (more brazing interfaces = less operator dependence)
 - But for future project, still some parts remain welded
- Optimization of EBW
 - Could it be replace by brazing? Two main parameters are to be considered:
 - TiN coating diffusion
 - RRR value decrease
- Single ceramic instead of Two
- TiN Coating: other material (Cr2O3, used on space tube) , none?
- Visual inspection: how to be independent from the operator?

Optimization for a mass production

Sample program: which optimization for QA?

➤ Example: RRR measurement

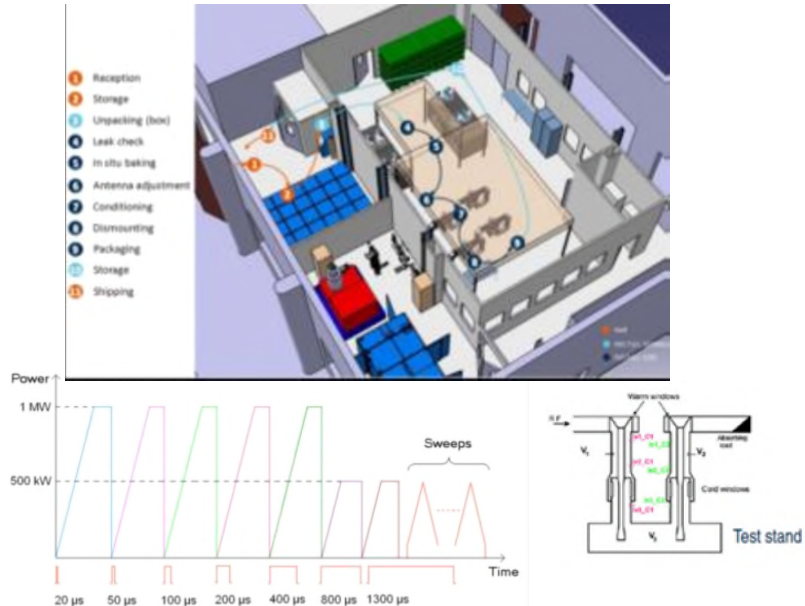
- If a RRR measurement is done each 2 month and 10 cpls/w what if RRR out of spec:
 - 80 couplers out of spec. and rejected?

➤ The same for copper coating thickness measurements.

Optimization for a mass production

RF conditioning strategy

- Is an RF conditioning foreseen for ILC ?
- Do you expect it to be done by a Lab or by manufacturer ?



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Was industrialization in line with original expectations ?

- More than 670 EU-XFEL & 140 LCLS II couplers manufactured by THALES/RI consortium
 - Pretty good reproducibility over quantities
 - Globally, QA and performances respected
 - Technology and skills acquisition (eg. copper coating on complex sub-assemblies)
 - R&D progress and know-how for all stakeholders
- Limited design modifications / new manufacturing processes accepted for Series production
 - XFEL - Only one bidder involved in industrialization process did actually participate to Series manufacturing
 - XFEL - Financial and planning variances for all Parties

Recommendations / proposal

- Truly involve industry at the early stage of couplers development to ensure “Design to cost” approach
- Connect when possible prototyping / industrialization phases to Series to mitigate technological and financial risks for all Parties
- Implement new technologies & designs (3D printing, Low SEY ceramics , single window...) by prototyping

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