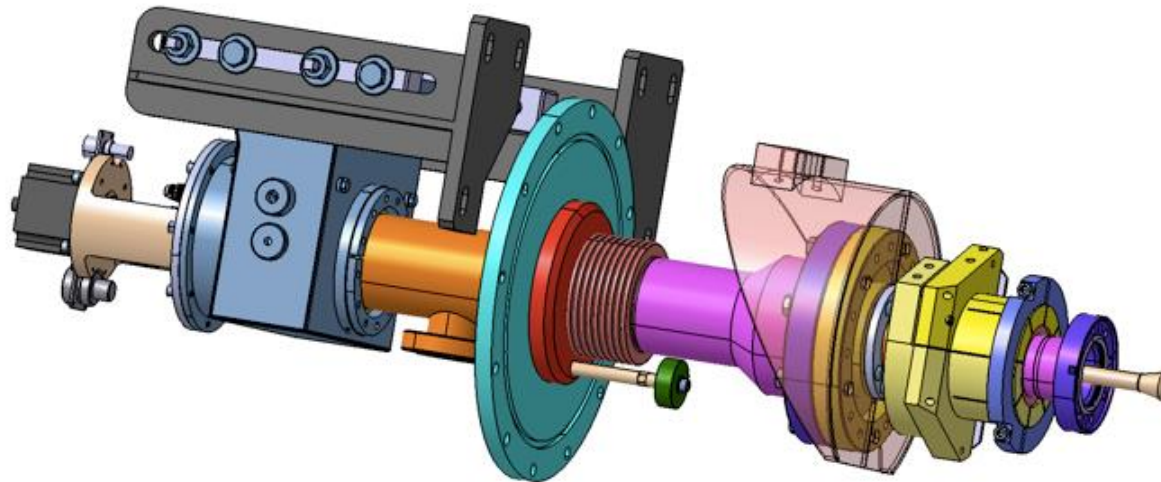


Issues faced during the XFEL mass production



Walid KAABI- LAL/CNRS

CERN, July 12th 2016

Outlines:



- **Introduction**
- **Fabrication process**
- **RF conditioning at LAL**
- **Troubles on the track**



800 power couplers 1.3 GHz are needed to equip **100 XFEL cryomodules**.

XFEL couplers are produced by 2 suppliers at 3 production sites:

- **Consortium Thales-RI** (Thonon les bains-France and Koln-Germany): **670** units.
- **CPI** (Beverly-Massachusetts-USA): **150** units.

Supported by DESY, LAL-Orsay has in charge:

- The **production monitoring** and the **quality control** at Thales-RI sites.
- The **RF conditioning** of all the couplers at Orsay and the weekly **delivery of 8 couplers/week** to IRFU-CEA (increased rate to **10 couplers/Week** since **January 2015**) .

Challenges:

- First experience in industrial monitoring at a such big scale,
- Successful know-how transfer to company: The clean room process & acceptance criteria,
- Rescaling the RF process at LAL to ensure the conditioning of 8 couplers per week,
- Respect of the overall project schedule.

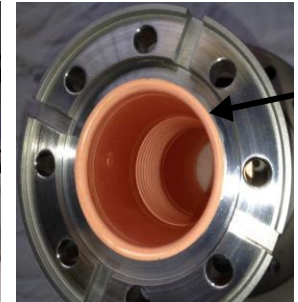
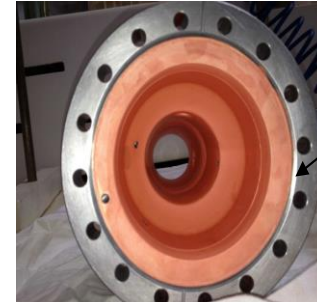
Fabrication process:



→
Brazing



→
Copper
plating



Inspection, then
Shipment to RI



←
Assembly
by pair

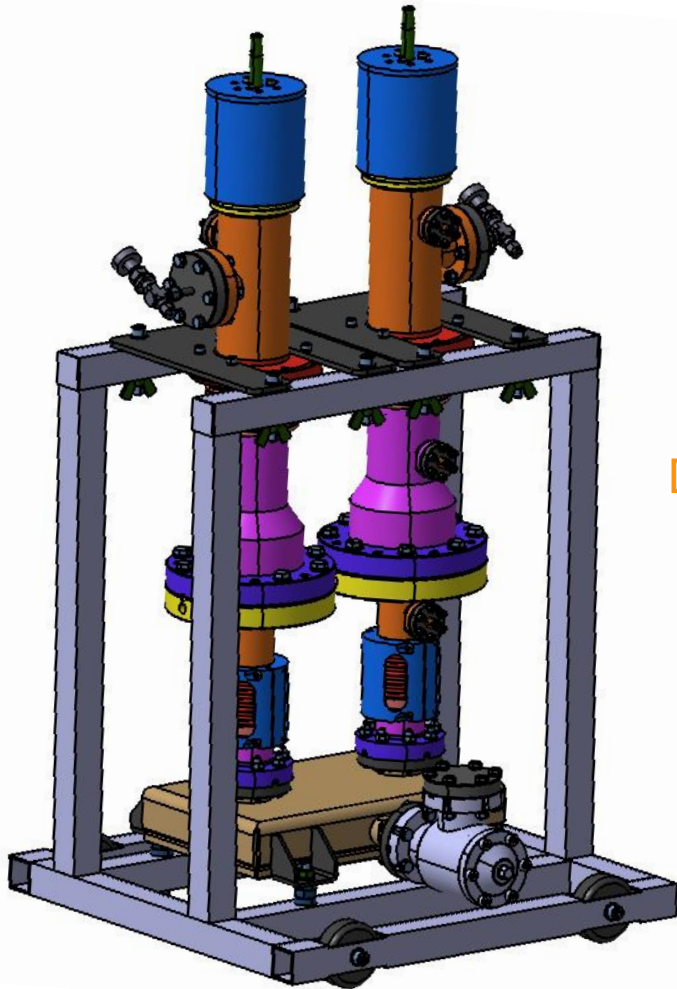


←
Cleaning,
drying,
particles
counting



Ceramics TiN coating
Ceramics EB welding

Fabrication process:



Delivery to LAL



RF conditioning at LAL:



Anritsu 03/29/2013 05:51:56 am

Points: 801

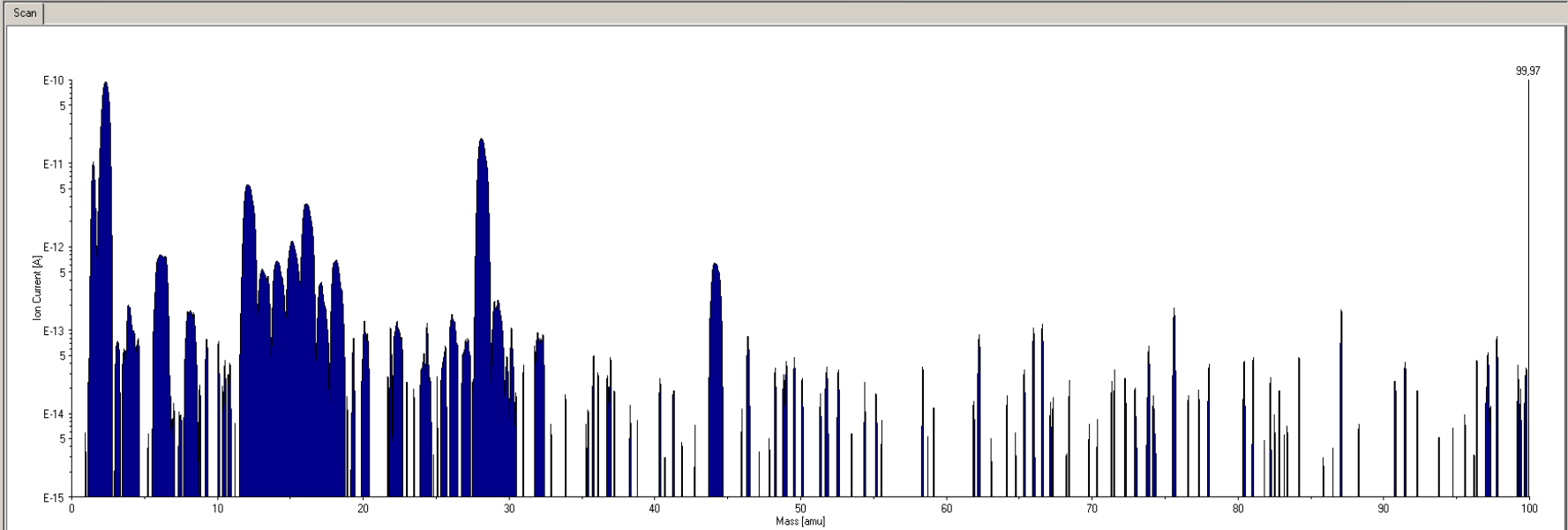
IFBW: 10 kHz

AVG: --

Power: High

Save

a b c



06/08/2015 08:56:44.080

06/08/2015 08:56:44.080

06/08/2015 08:57:43.688

06/08/2015 08:57:44.080

06/08/2015 08:57:44.080

1min

TR4: S22
Log Mag
Smooth: 0 %
CAL: ON (OK)
10.00 dB/
Ref 0.00 dB

-50.0	-50.0
-60.0	-60.0
-70.0	-70.0
-80.0	-80.0

1.200 GHz TR3 1.400 GHz 1.200 GHz TR4 1.400 GHz

MK1 TR1: 1.300 GHz,LM:-51.93 dB
MK2 TR2: 1.300 GHz,LM:-0.10 dB
MK3 TR3: 1.300 GHz,LM:-0.11 dB
MK4 TR4: 1.300 GHz,LM:-46.08 dB

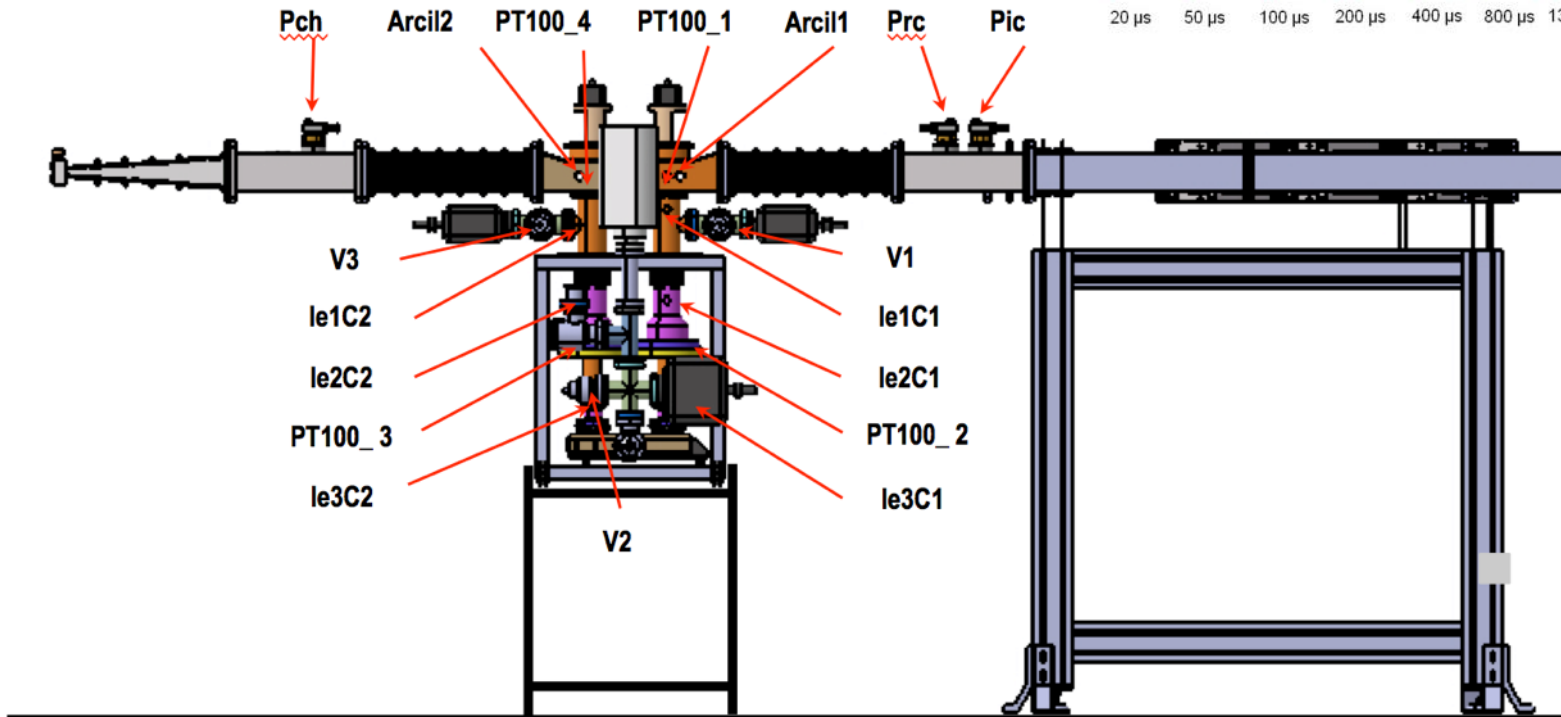
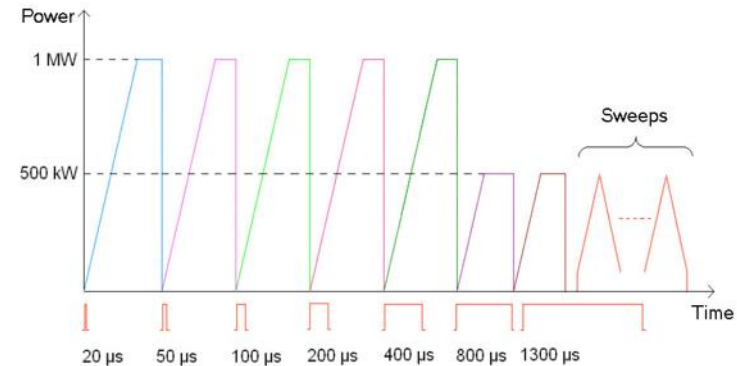
Change
Save
Location
Change Type
Setup/JPEG/...

Freq Scale Sweep Measure Marker

RF conditioning at LAL:



Vacuum	1 st threshold (0.1 dB): SV1	6.10 ⁻⁷ mbar
	2 nd threshold (0.4 dB): SV2	2.10 ⁻⁶ mbar
	Interlock: IL	5.10 ⁻⁶ mbar
e- current IL	8 mA	
Light IL	none	
Ceramic Temperature IL	60°C	
WG arc IL	If any	
Control loop duration(0.1 dB)	15 s	



RF conditioning at LAL:



STATION DE CONDITIONNEMENT DES COUPLEURS XFEL

*** POSTE DE SUPERVISION ***

Mode Expert

Commande Mode Station

Etat Mode Station

PULSING

PULSING

Version 5.0 du 06/06/2014

Alimentations Alarmes Modulateur HT Paramètres Station Conditionnement Coupleurs XFEL Graphes Graphes Temp. Interlock Image

N° Séquence: 271, N° d'étape: 4, N° de balayage: 0

Etat Station: PULSING, MAPR: Reprise

Etat Conditionnement: Reprise, Type_Echec: RAS

Temps de l'étape: 137 mn, Temps du Conditionnement: 775 mn

Niveau de puissance Synthé RF: -5,6 dBm

Fr: 4 Hz, Largeur Impulsion: 200 us, Pi_max: 1000 kW

Nb Interlock Coupleurs: 0, Nb Interlock Station: 0

Niveau de Puissance avant Interlock: -13,15 dBm, N° étape avant Interlock: 0, dPil (dB): 0,2875

Puissance Klystron

Psi_K (kW): 3792,98, Ros_K: 1,16, Psi_K (dBm): 95,79

Psr_K (kW): 21,13, Psr_K (dBm): 73,25

Reset Graphe

Choix Courbe 2: vides, Choix Courbe 1: Pic

Choix_voie: A

Num_P: 147, Pic: 1007,3 kW, Pch: 980,5 kW, Prc: 4,5 kW

Pickup: 1,4, 1,1, 1,7, 2,1, 1,8, 0,3, V: 2,1

Vides: 2,3E-7, 1,4E-7, 4,8E-7, mBar, Vide Max: 4,8E-7

Valeurs max des x mesures

D: 3023,7 V, C: 4,8E-7 mBar

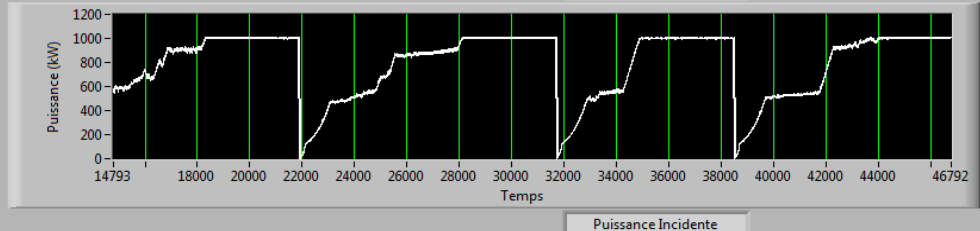
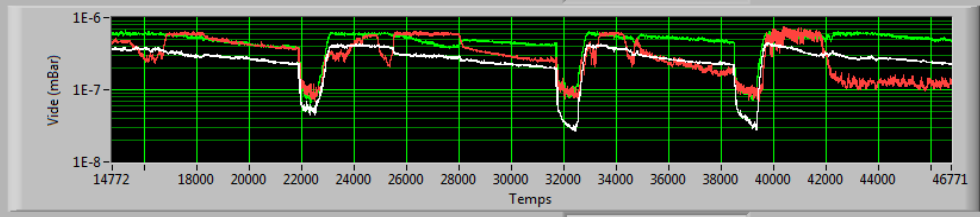
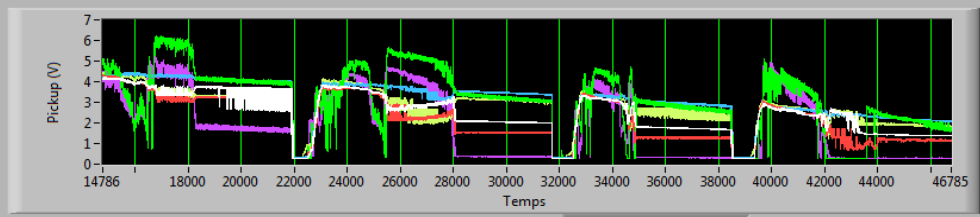
Vide lent Klystron (µA): 0,582

Raz Defaults Servitudes Klystron

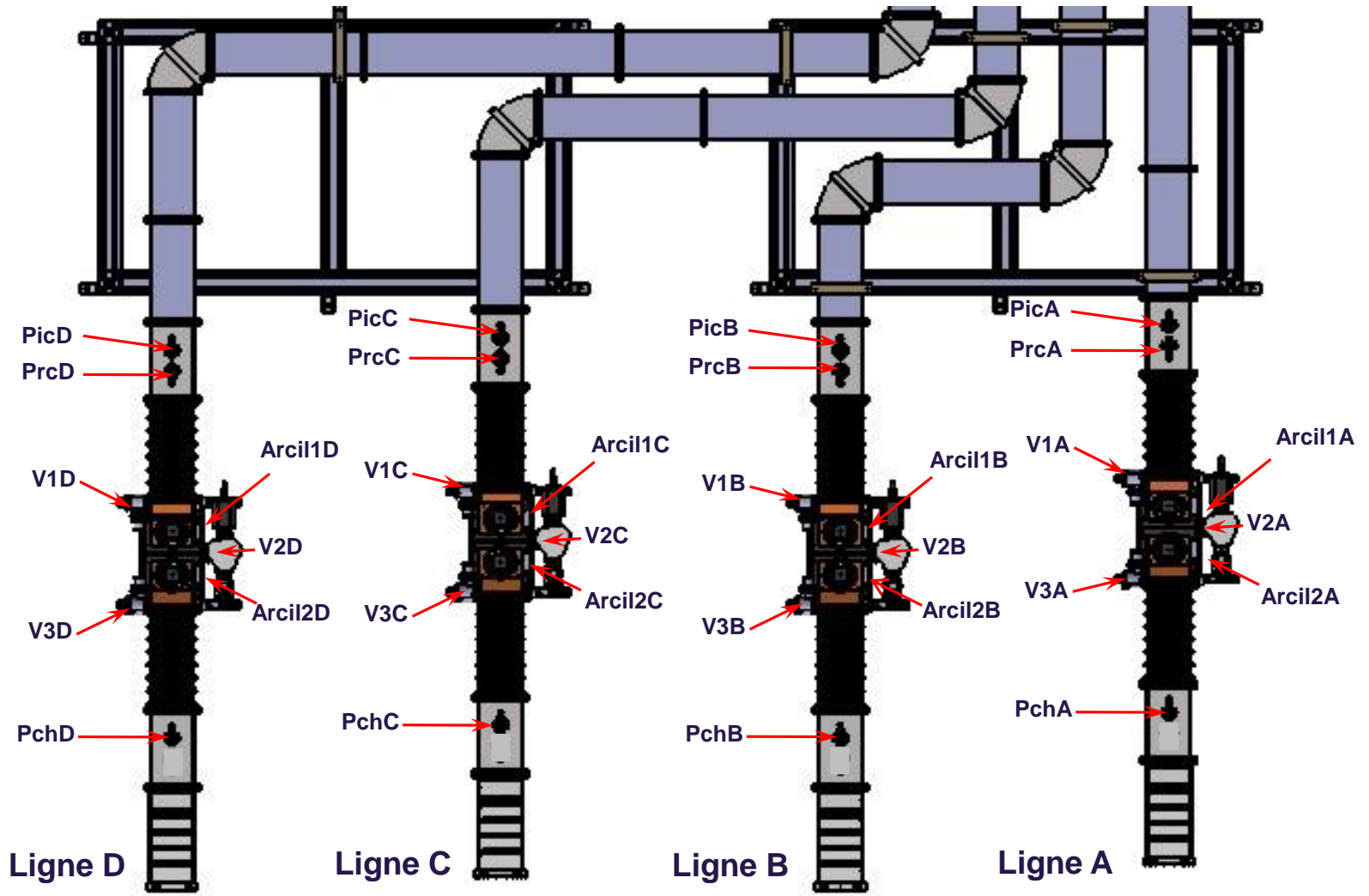
- Alims ON
- Défaut alimentations
- Défaut Modulateur
- Défaut Détecteurs d'Arc
- Défaut Klystron
- Défaut Sécurités Batiment
- Défaut Températures
- Défaut liaison Modulateur HT
- Défaut Coupleur

Niveau_RF (dBm): -30,0

STOP SUPERVISION



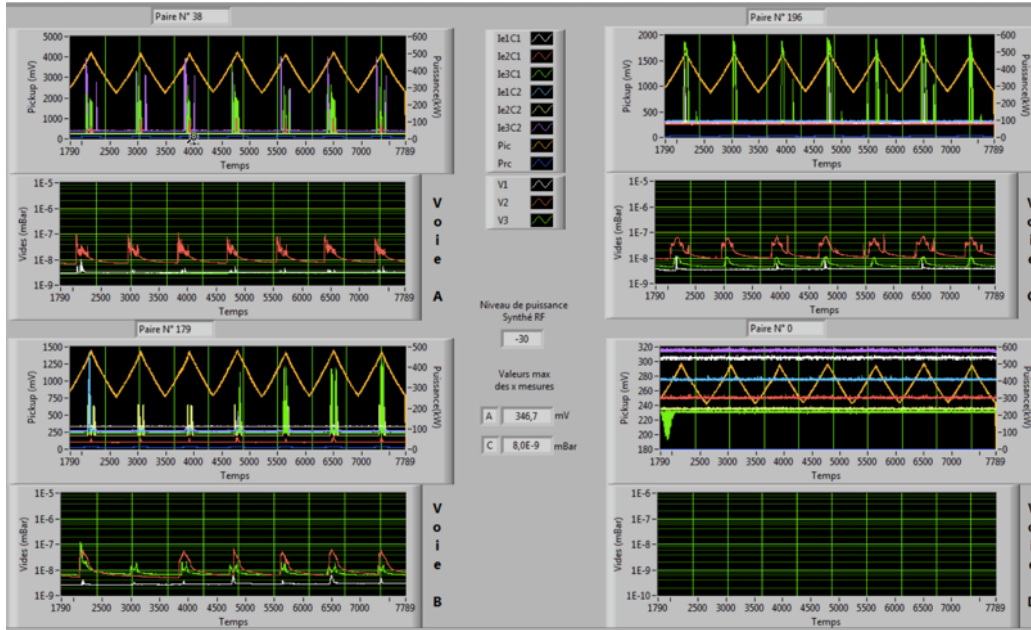
RF conditioning at LAL:



RF conditioning at LAL:



RF conditioning at LAL:



Shipment to IRFU-CEA

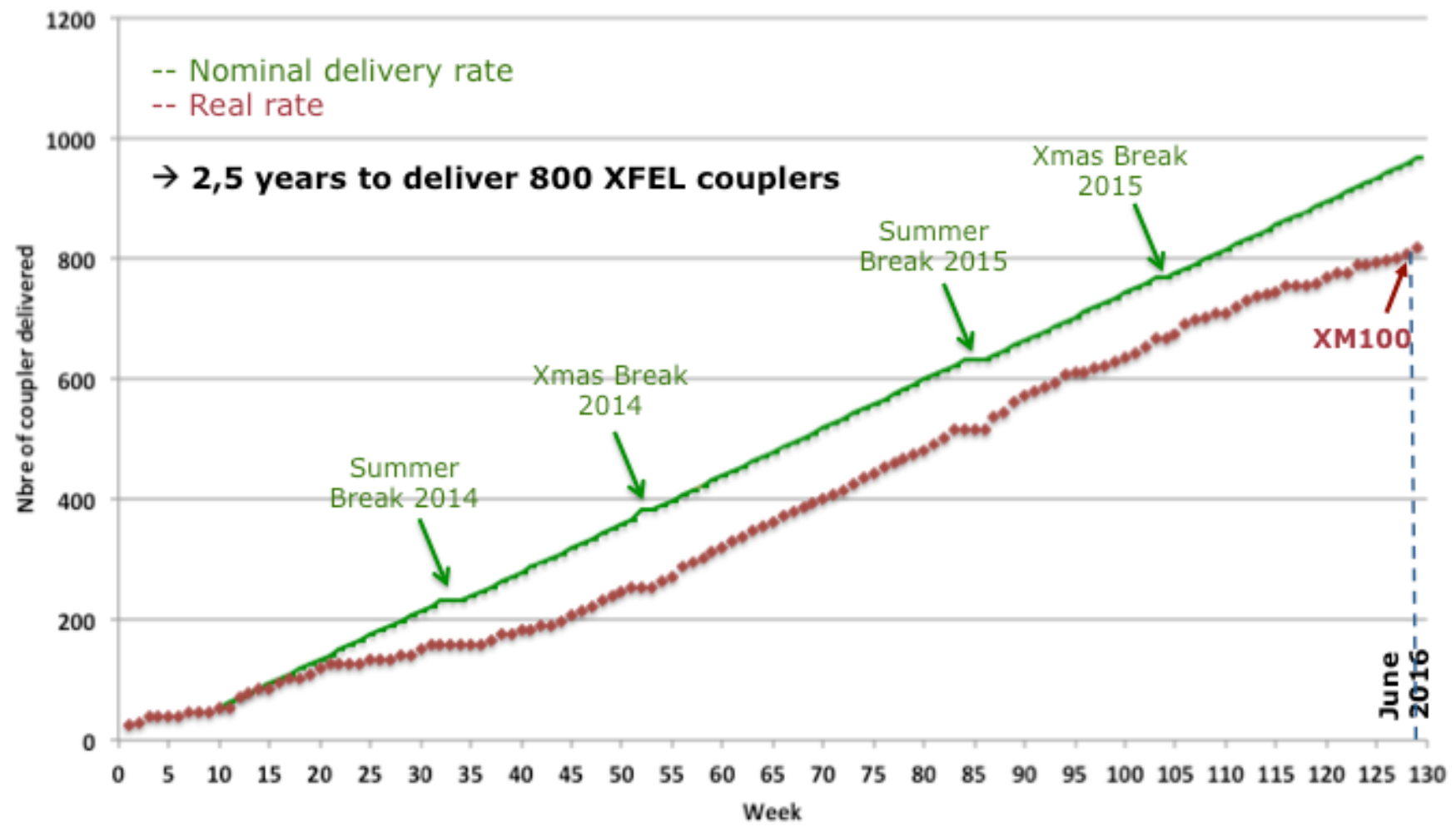


Coupler pair disassembly
& final inspection

RF conditioning at LAL:



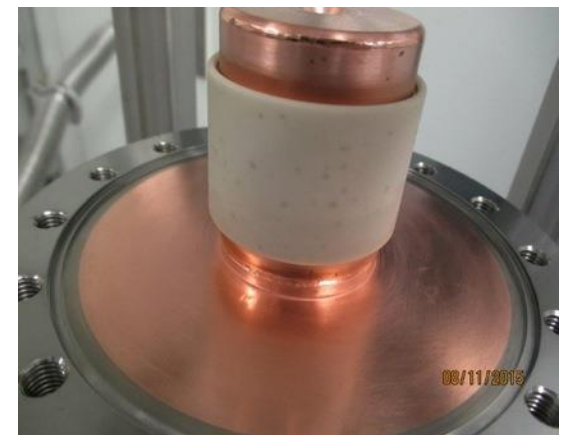
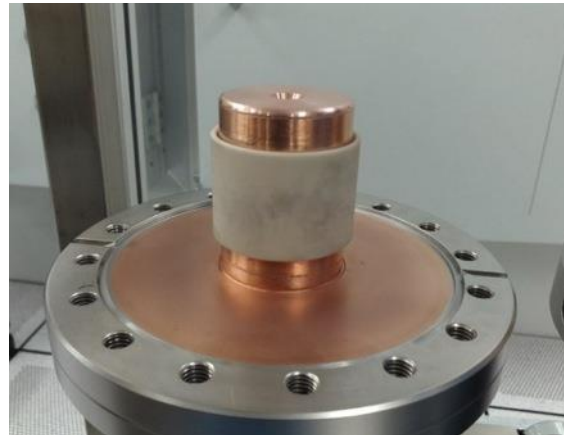
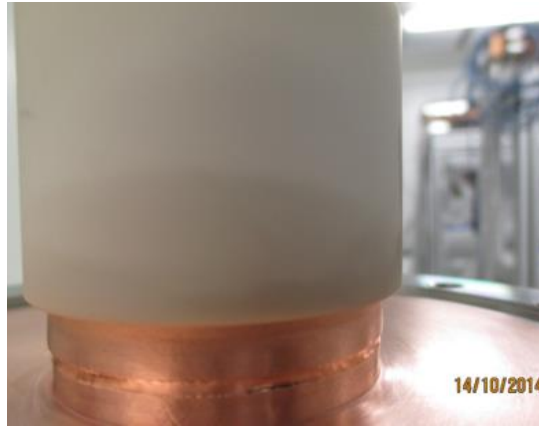
LAL to IRFU deliveries (2014-2015-2016)



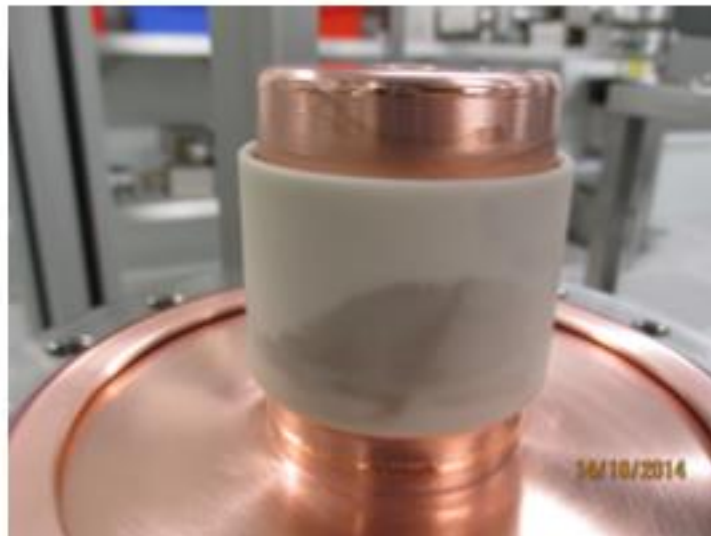
Troubles on the track: Dark layer on cold ceramic



Main defect discovered during the final inspection: **Dark layer in cold ceramic window**

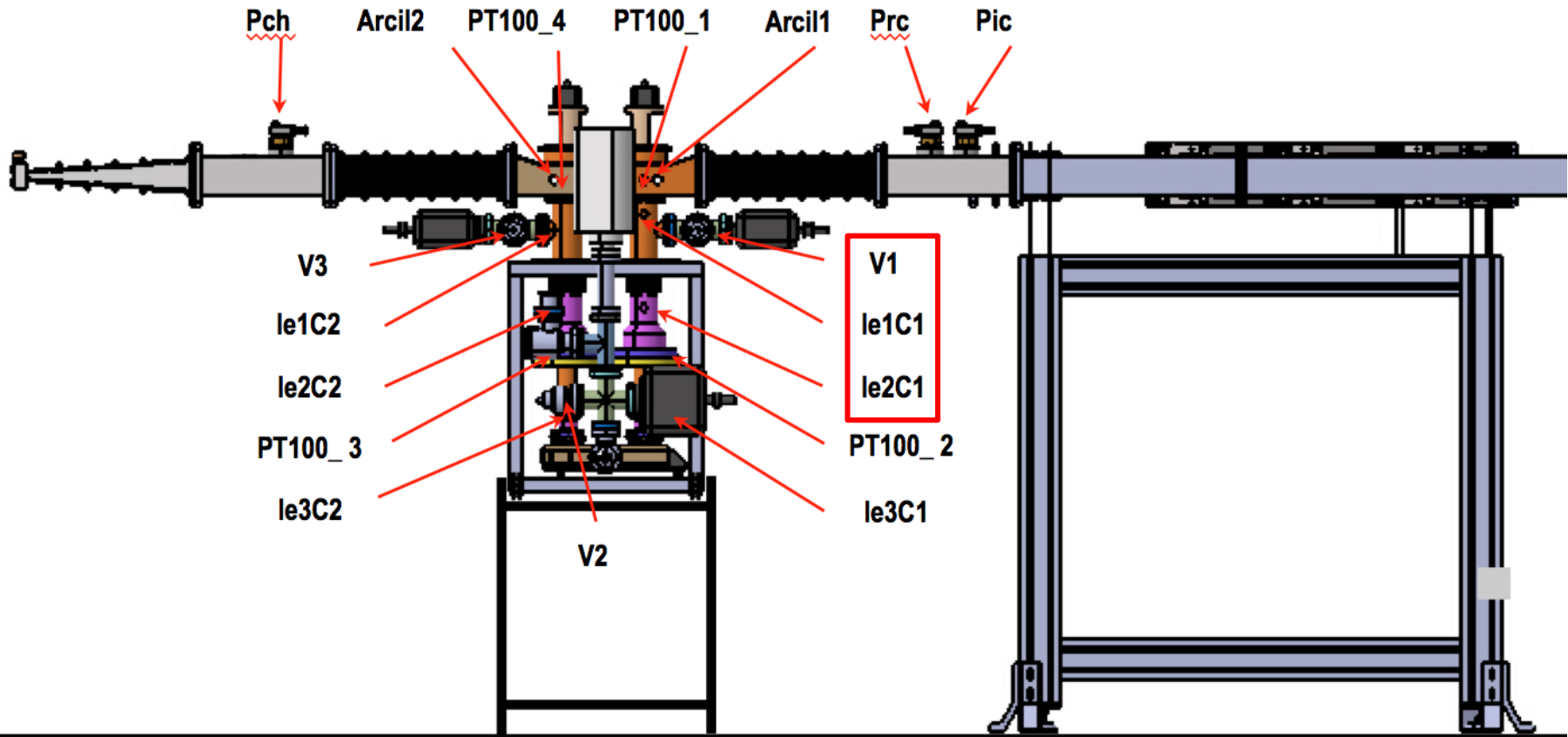


Troubles on the track: Dark layer on cold ceramic

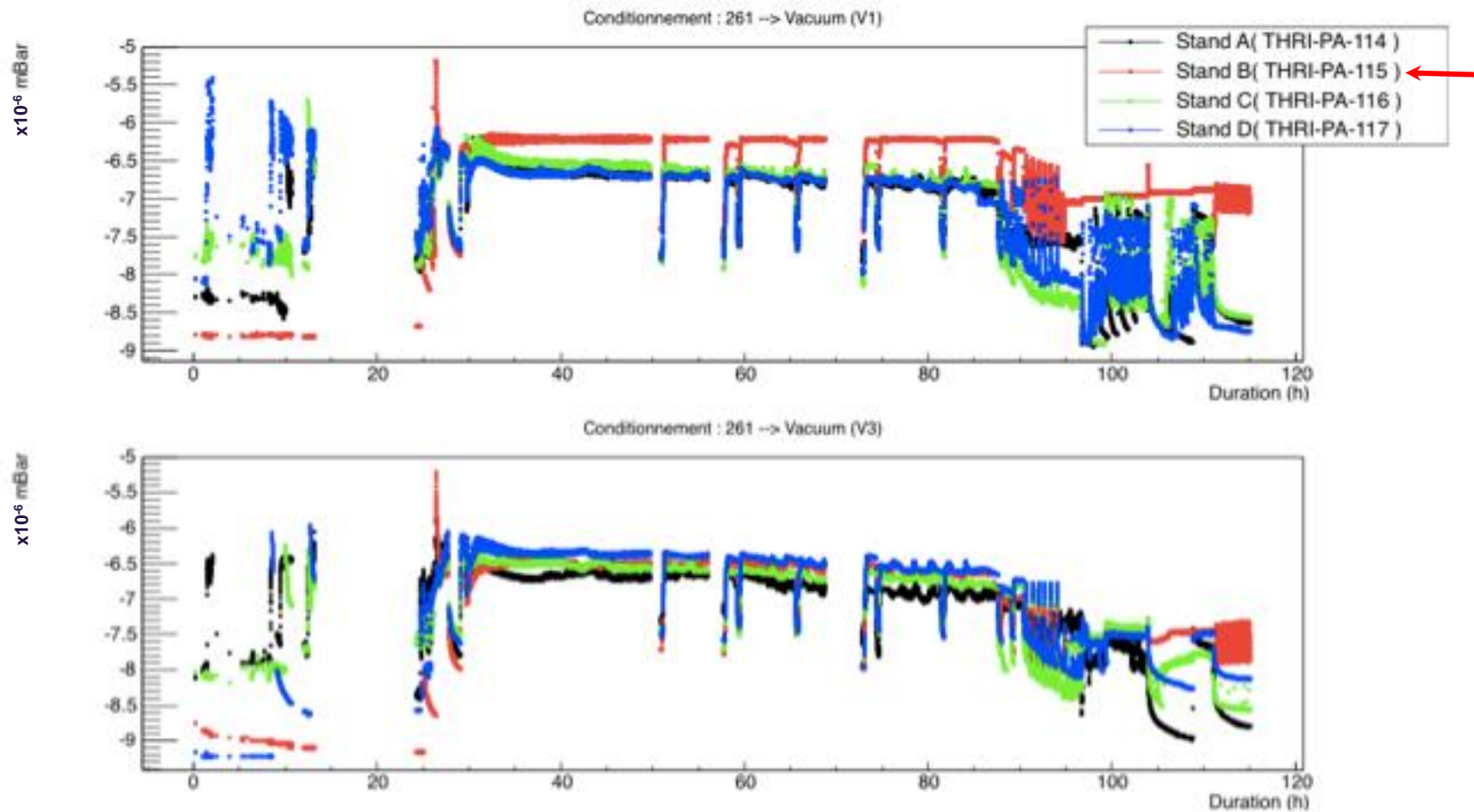


CP 331_Pair 115
Upstream coupler

Troubles on the track: Dark layer on cold ceramic



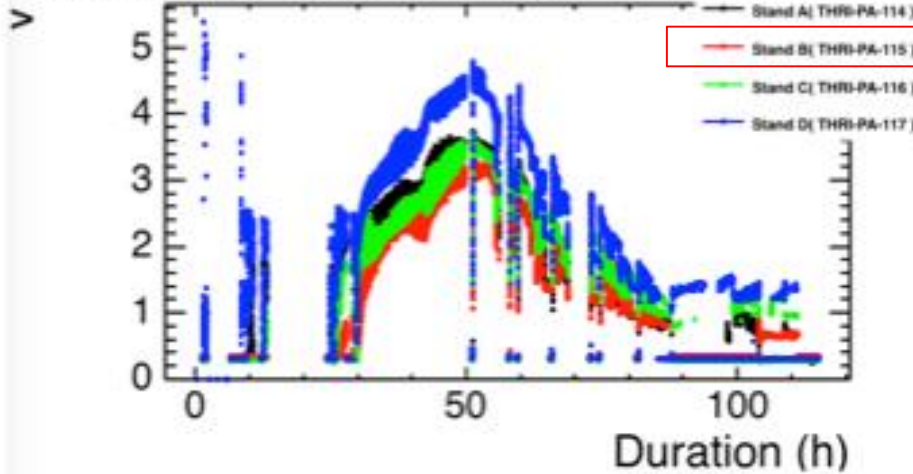
Troubles on the track: Dark layer on cold ceramic



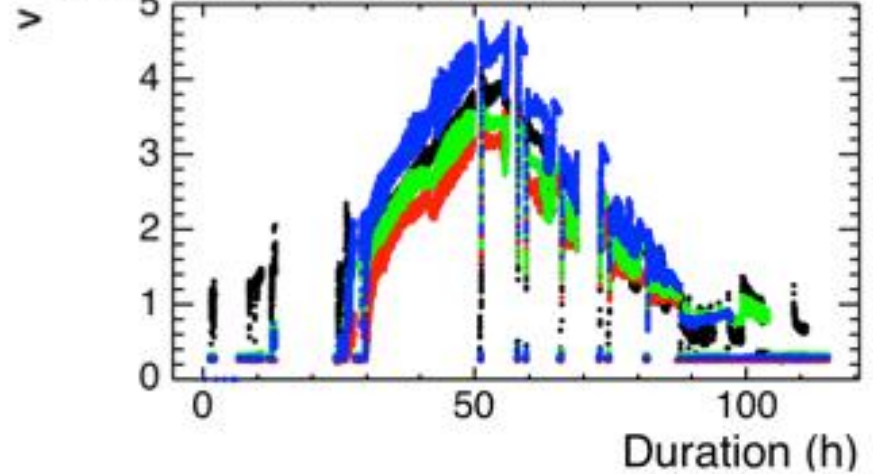
Troubles on the track: Dark layer on cold ceramic



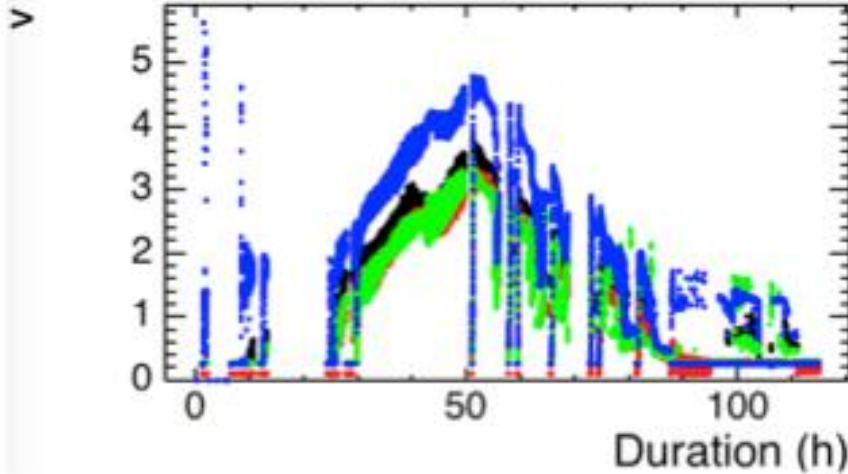
Conditionnement : 261 → Pickup (Je1C1), All steps



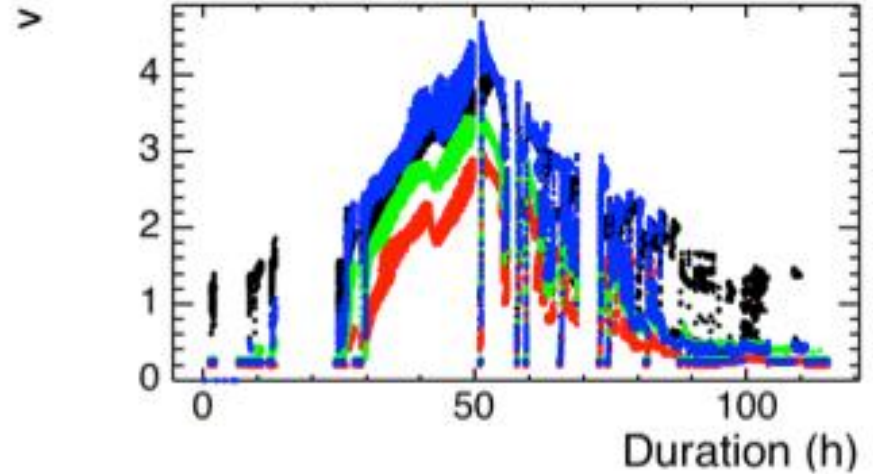
Conditionnement : 261 → Pickup (Je1C2), All steps



Conditionnement : 261 → Pickup (Je2C1), All steps



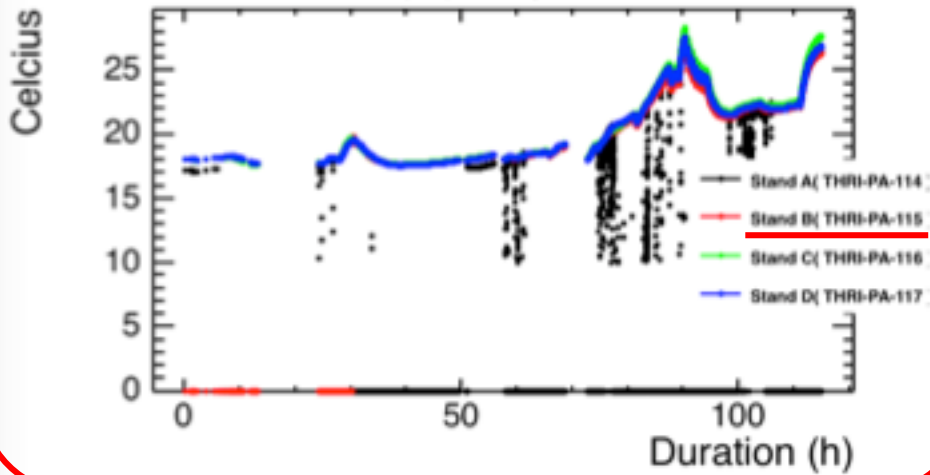
Conditionnement : 261 → Pickup (Je2C2), All steps



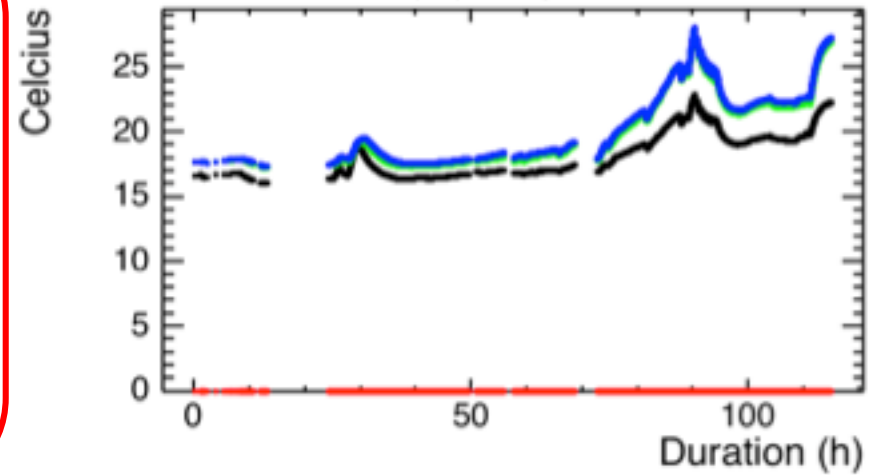
Troubles on the track: Dark layer on cold ceramic



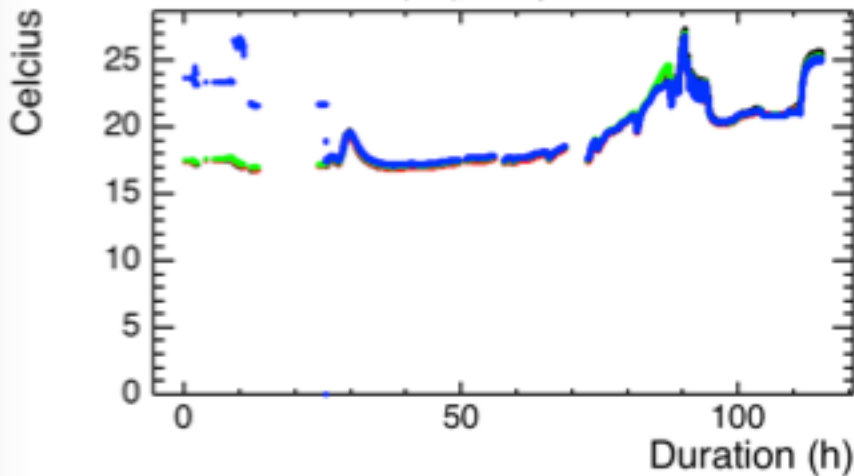
Conditionnement : 261 -> Vacuum (T1c), All steps



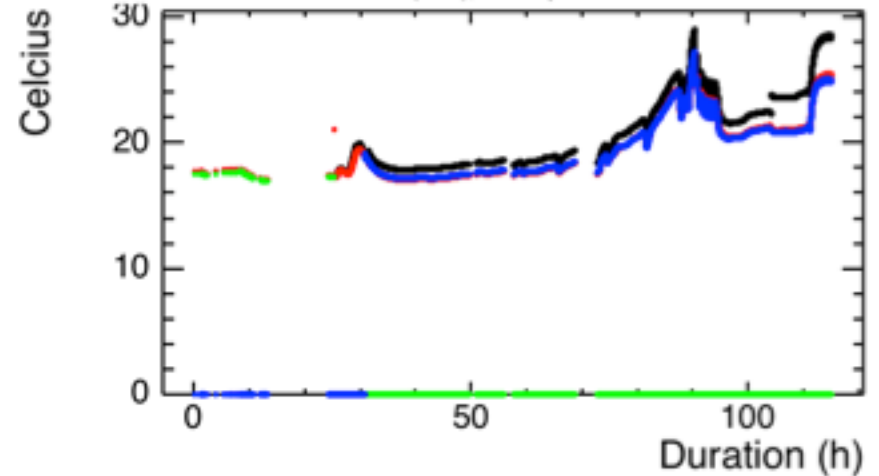
Conditionnement : 261 -> Vacuum (T2c), All steps



Conditionnement : 261 -> Vacuum (T1w), All steps



Conditionnement : 261 -> Vacuum (T2w), All steps



Troubles on the track: Dark layer on cold ceramic

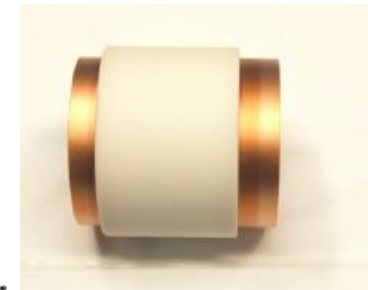
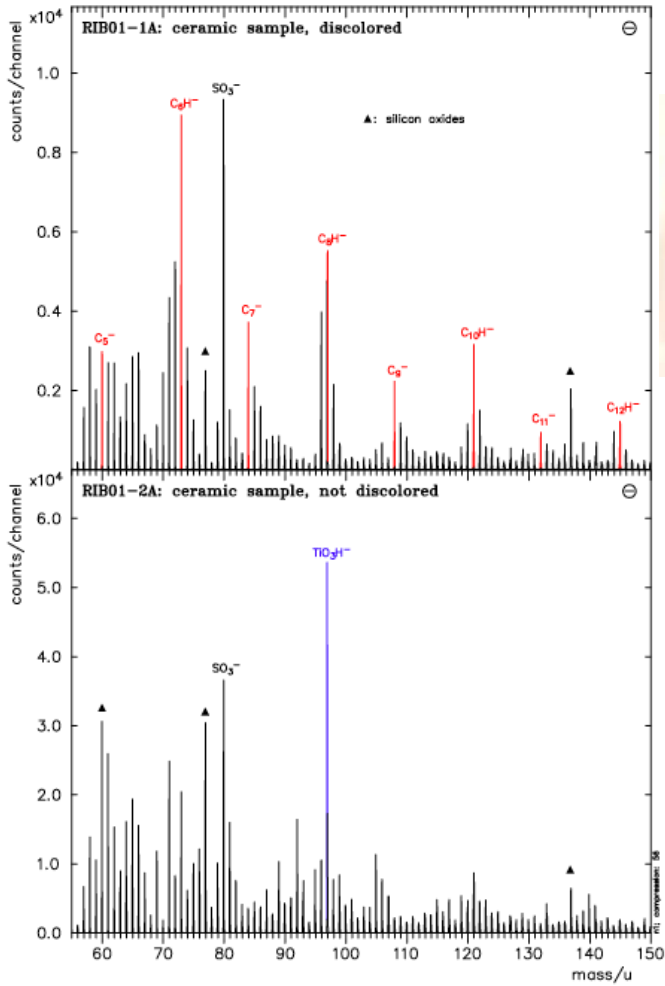


Figure 4: Details of the TOF-SIMS spectra of negative secondary ions

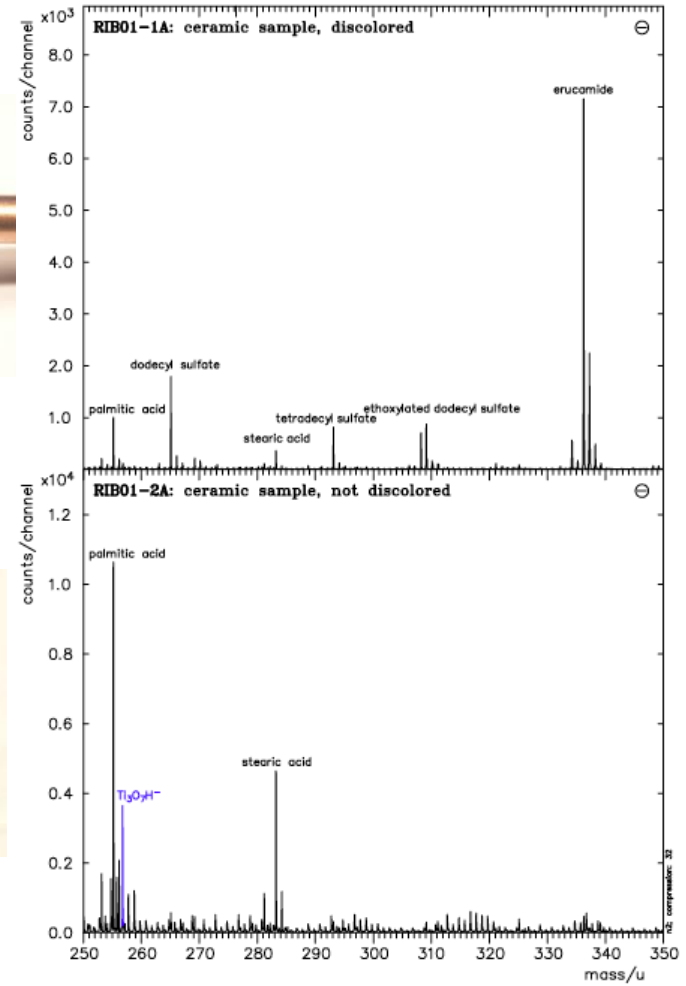


Figure 5: Details of the TOF-SIMS spectra of negative secondary ions

Troubles on the track: Dark layer on cold ceramic



OFG - Analytik

Oberflächen - Festkörper - Grenzflächen Analytik GmbH
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OFG - Analytik

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5. Results of the TOF-SIMS Analyses

5.1. Summary

The main results are^{1,2}:

- In the spectra of sample 2 (not discolored) mass signals of **titanium**, **titanium oxides** and **silicon oxides** as well as mixed **silicon/titanium oxides** are distinctly observed (look at figures 4 and 5 on pages 8 and 9). Moreover **chlorine**, **higher fatty acids** (figure 5 on page 9) and the additive **4,4'-Bis(diethylamino)benzophenone** are detected with high signal intensities.
- In the spectra of both preparations **sodium**, **potassium**, **calcium** and **CN/CNO-** as well as **SO₂ anions** are identified with high signal intensities.
- Only in the spectra of the discolored sample 1 the lubricant **erucamide** (figure 5 on page 9) and **soot-like carbon anions** (C₂H⁻, figure 4 on page 8) as well as **alkylsulfates** (figure 5 on page 9) are clearly detected.

Further elements and compounds are detected mostly with low intensities, partly in the range of the detection limit. Table 1 gives a qualitative survey of the detected elements and compounds.

5.2. Comment

While in the spectra of the not discolored sample the ceramic material is distinctly observed, particularly erucamide and soot-like carbon anions are detected in the spectra of the discolored surface. The former compound can probably be attributed to the plastic wrapping of this sample (→ as-received condition). However the soot-like carbon anions (→ carbon black) can possibly be associated with the observed discoloration.

5.3. List of established elements / compounds

The specified elements / compounds are established with different intensities on the sample surfaces. Meaning of: — → not detected, □ → near the detection limit, ■ → very small intensity, ■■■ → medium intensity and ■■■■■ → very high intensity relative to basepeaks, substrate signals, signals of hydrocarbons or signals in comparable reference-spectra.

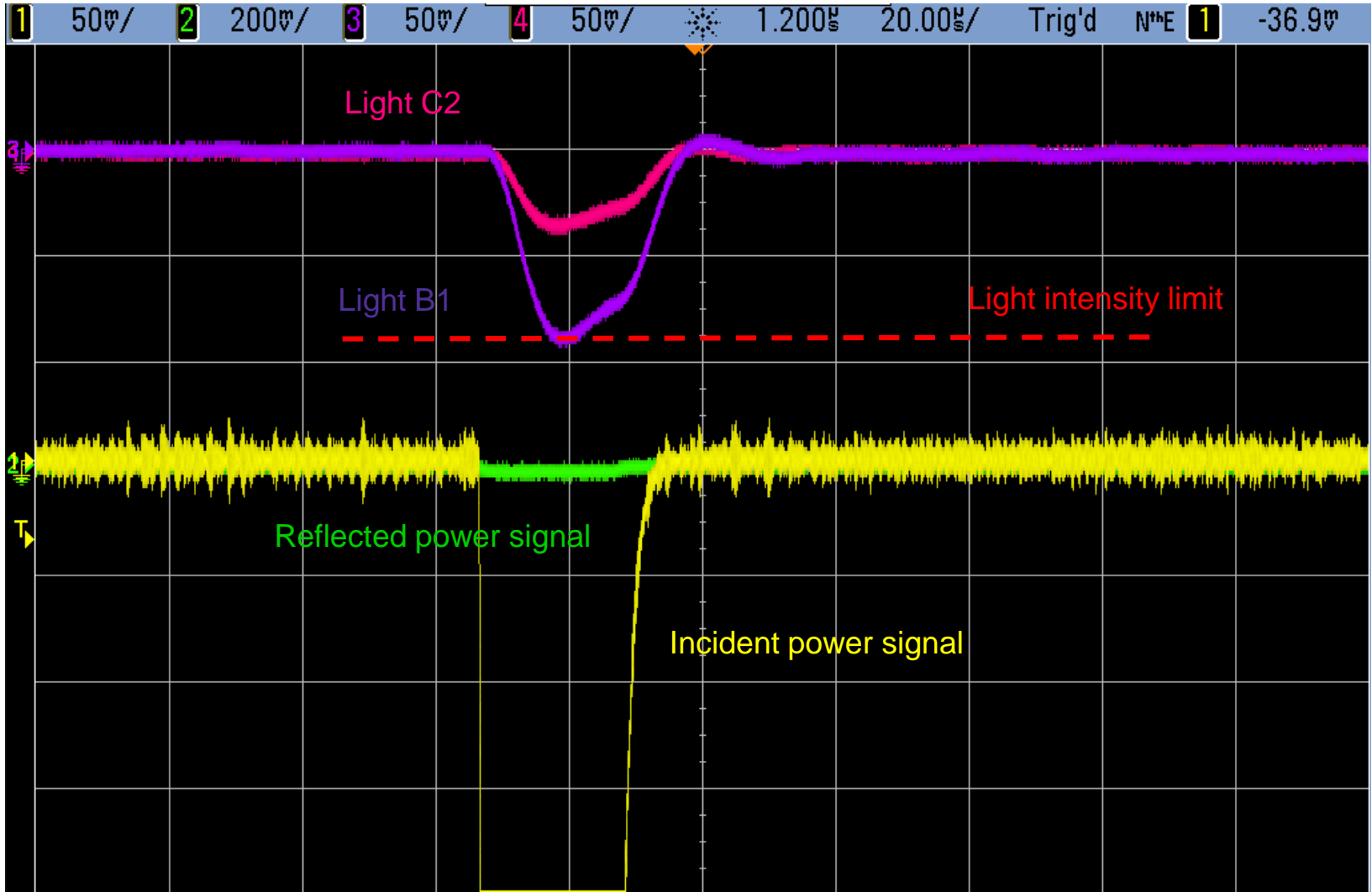
substance	prep. (RIB01-)					
	1A	2A				
additives:						
4,4'-Bis(diethylamino)benzophenone	■■■■■	■■■■■				
Irgafos 168	■	□				
alkaline/alkaline earth metals:						
calcium/calcium hydroxide	■■■■■	■■■■■				
potassium	■	■				
magnesium	□	■				
sodium	■■■■■	■■■■■				
sodium hydroxide	□	■				
sodium sulfate	□	■				
anions (semipositive):						
CN ⁻ /CNO ⁻	■■■■■	■■■■■				
NO ₂ ⁻	■	■				
PO ₄ ⁻	□	■				
SO ₂ ⁻	■	■				
half metals:						
silicon	■	■				
silicon oxides	■	■				
silicon/titanium oxides	—	■■■■■				
fatty acid amides:						
erucamide	■■■■■	—				
diglycerides	□	—				
fatty acids:						
higher fatty acids	■	■■■■■				
halogens:						
fluorine	■	■				
chlorine	■	■				
metals / metal compounds:						
aluminium	—	□				
chrom	—	□				
copper	□	□				
mangan	□	□				
titanium/titanium dioxide	□	■■■■■				
tin	—	□				
silicones:						
poly(dimethyl siloxane)	■	■				
anionic surfactants:						
alkylsulfates	■	□				
sulfur	□	□				
C ₂ H anions (→ soot/carbon black)	■■■■■	—				

Table 1: Relative intensities of representative signal peaks for the investigated samples (Note: intensities within a single column are not comparable).

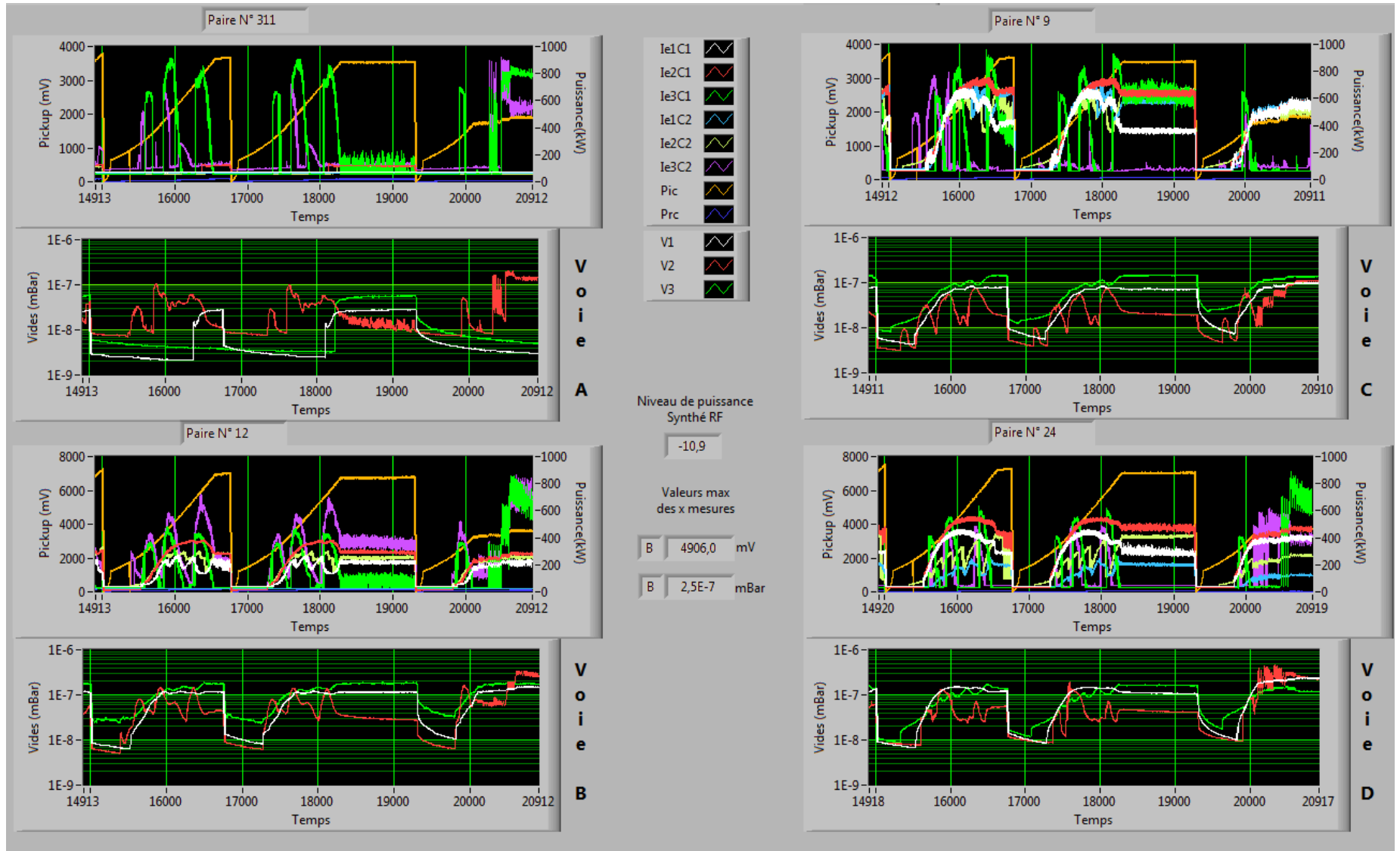
¹The analyses were carried out according to procedure OFG-P1. The results were obtained by comparison with databases.

²Comments are set in italic text.

Troubles on the track: Light & arcing in the warm windows



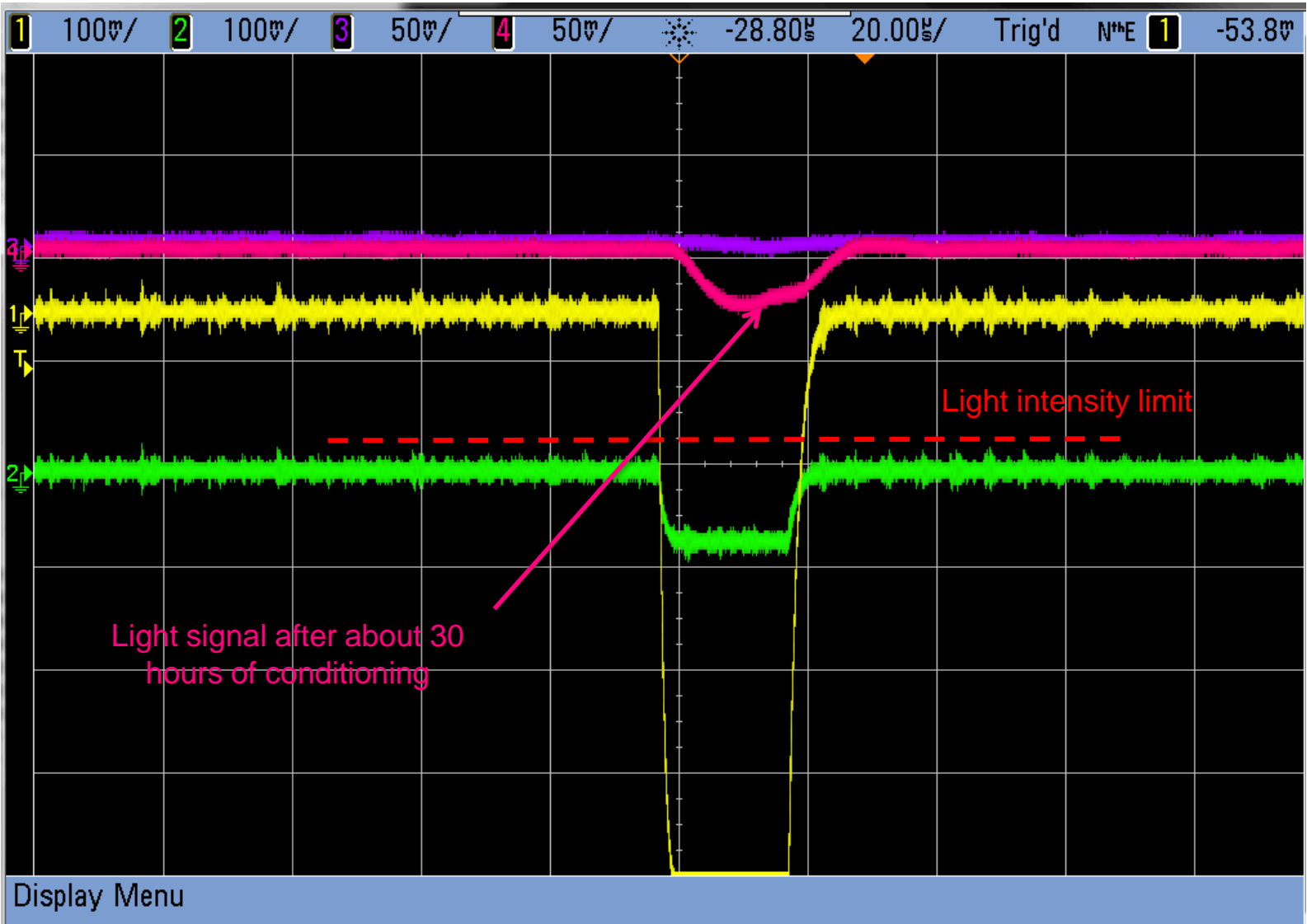
Troubles on the track: Light & arcing in the warm windows



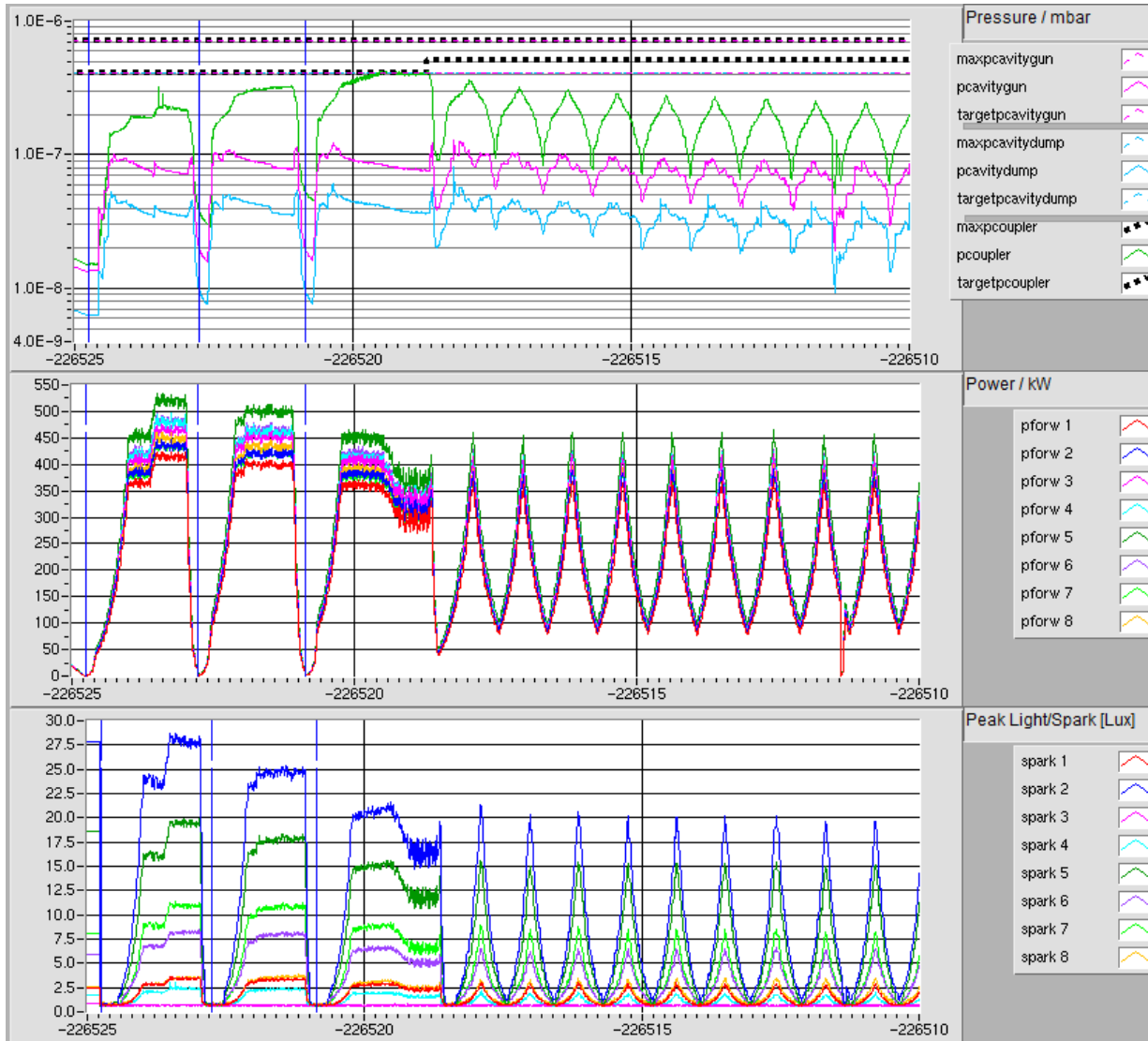
Troubles on the track: Light & arcing in the warm windows



Troubles on the track: Light & arcing in the warm windows



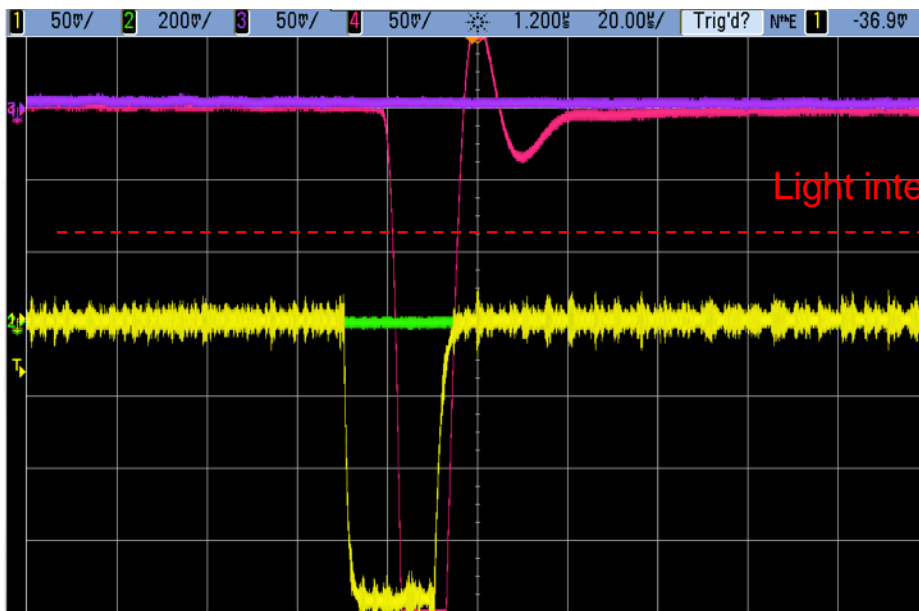
Troubles on the track: Light & arcing in the warm windows



Module XM-1 couplers conditioning:
Light signal on spark sensors

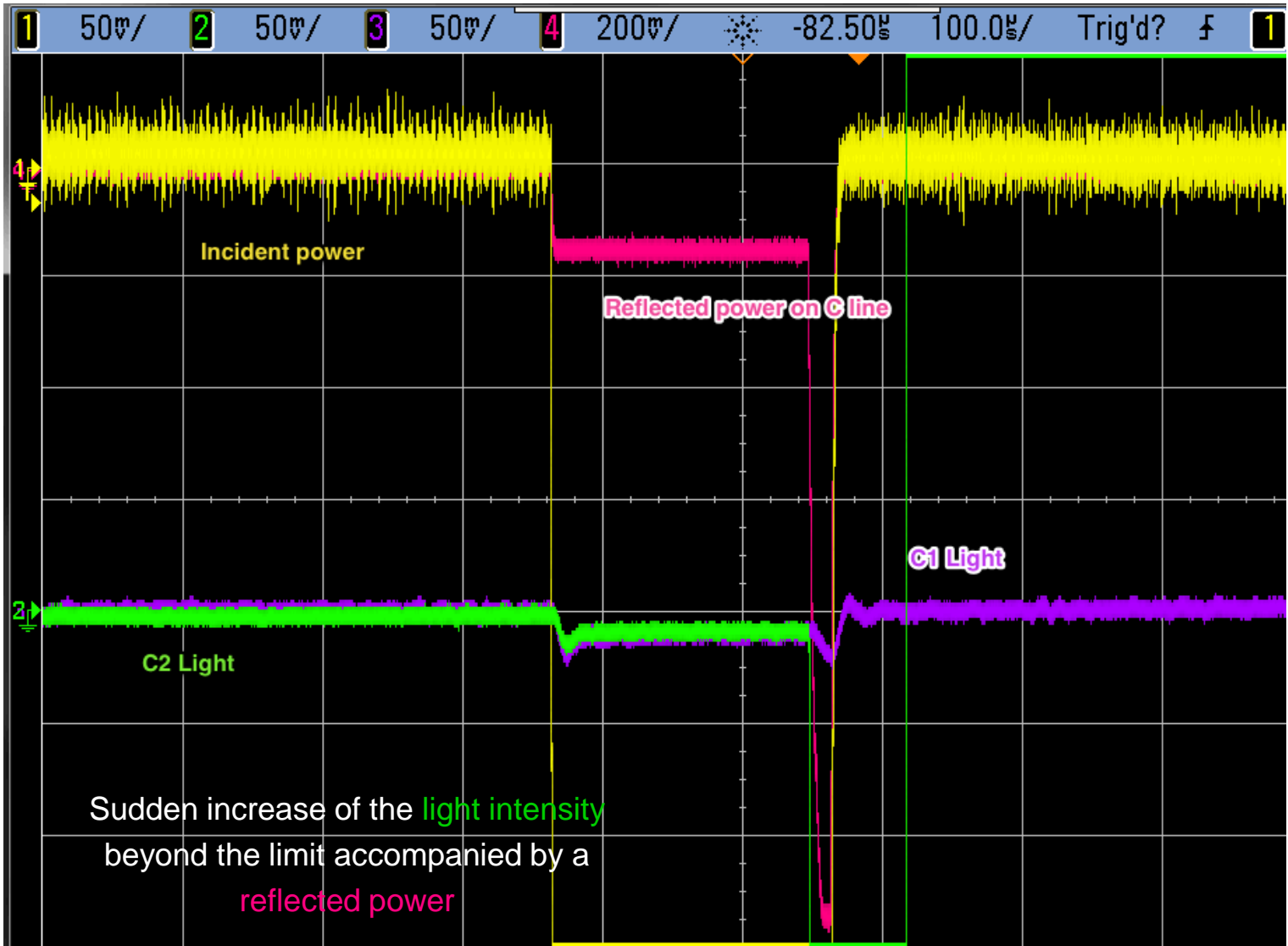
Denis Kostin, MHF-sl, DESY

Troubles on the track: Light & arcing in the warm windows



Sudden increase of the light intensity causing arc interlock: generally occurs at low power (under 250 W) at the shortest pulse (20us) → impossible to go further: the pair is removed from the test stand.

Troubles on the track: Light & arcing in the warm windows

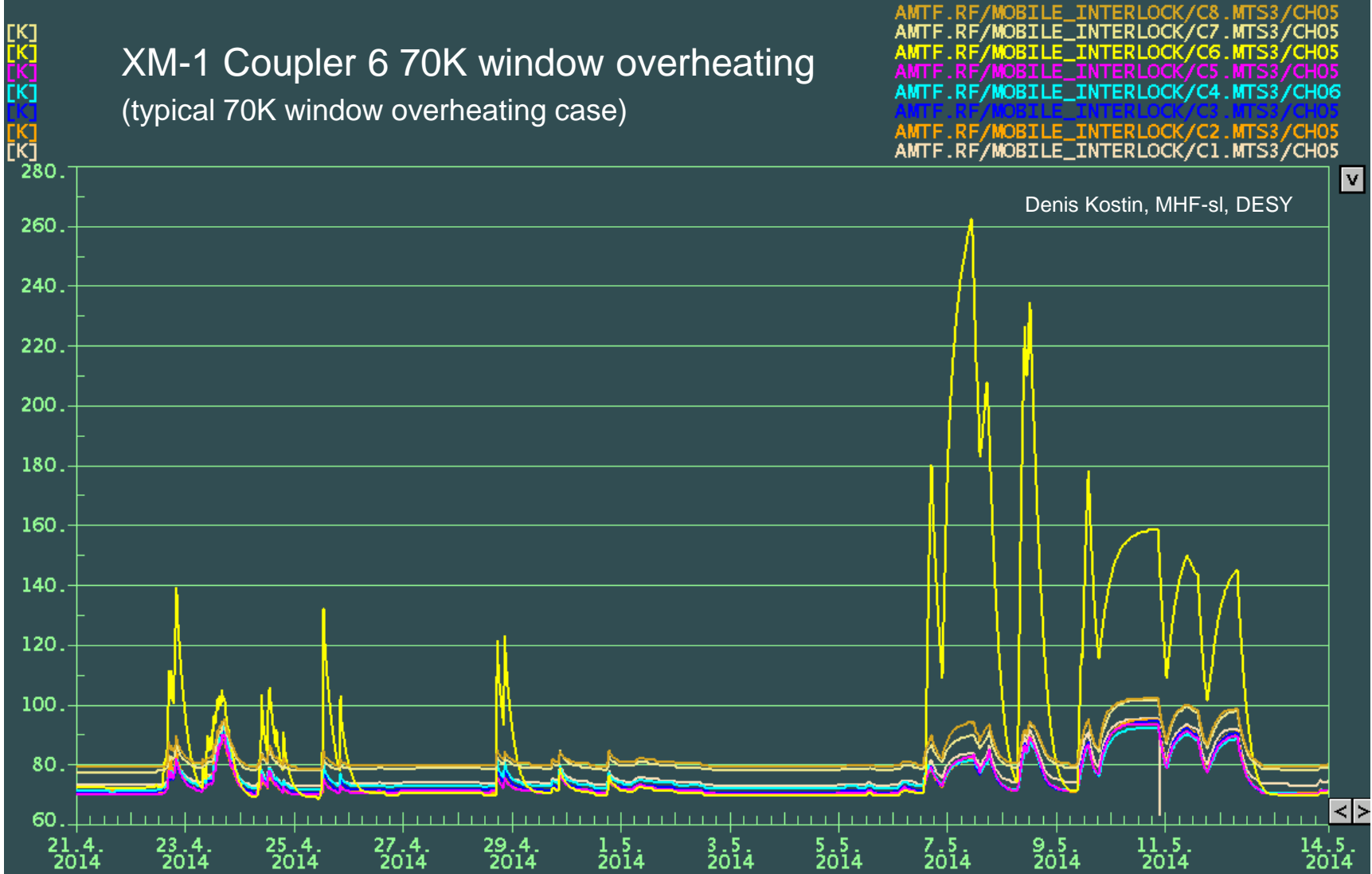


Sudden increase of the light intensity beyond the limit accompanied by a reflected power

Troubles on the track: Overheating during RF test



XM-1 Coupler 6 70K window overheating
(typical 70K window overheating case)

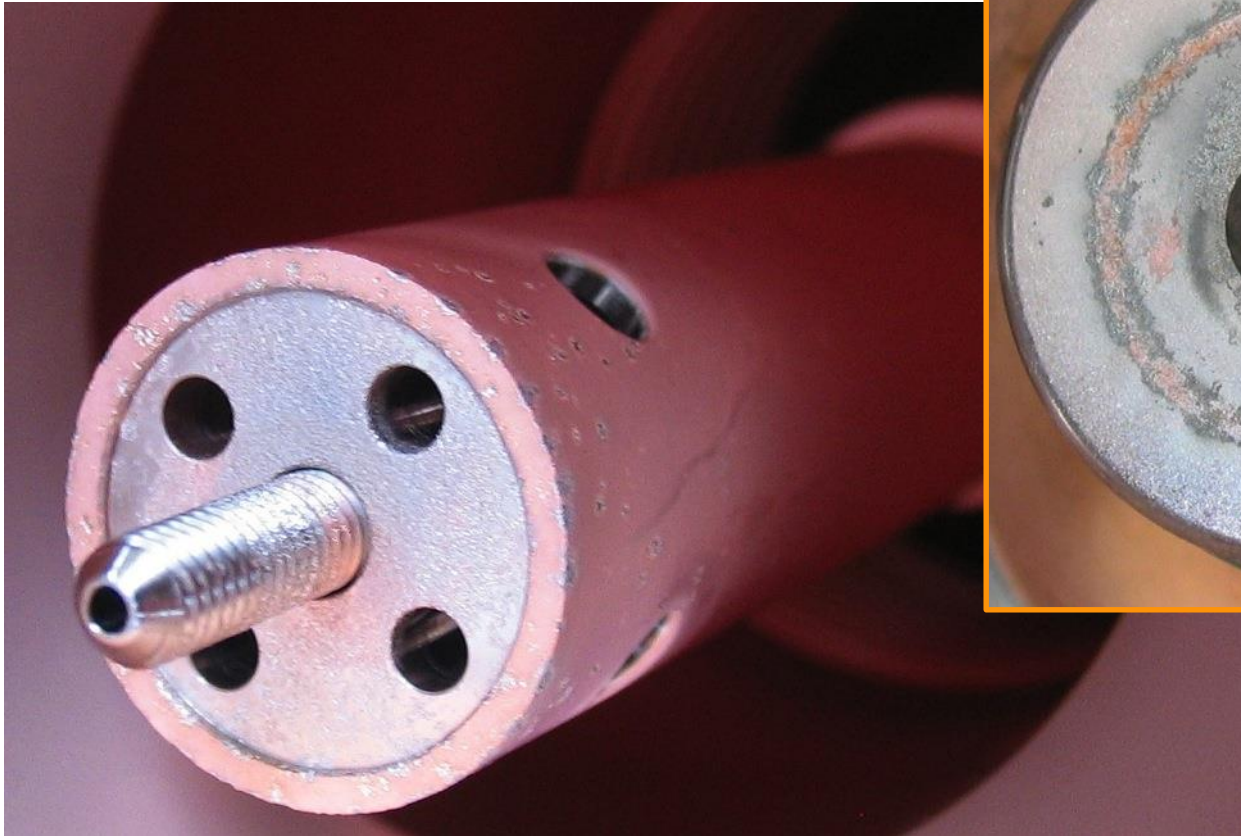


Troubles on the track: Overheating during RF test



Coupler 70K window overheating due to loose connection between the WIC and the CP. Cold part must be grinded and cleaned. The WP must be changed.

Re-conditioning takes long time: cleaning is difficult, no baking, no US-wash...

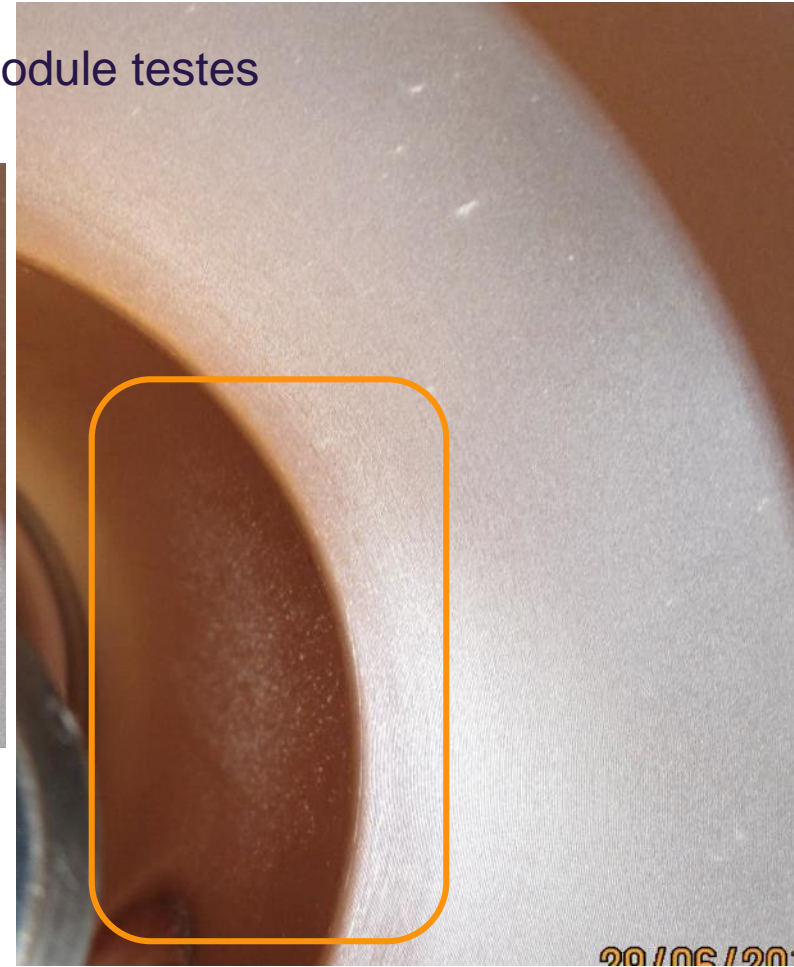
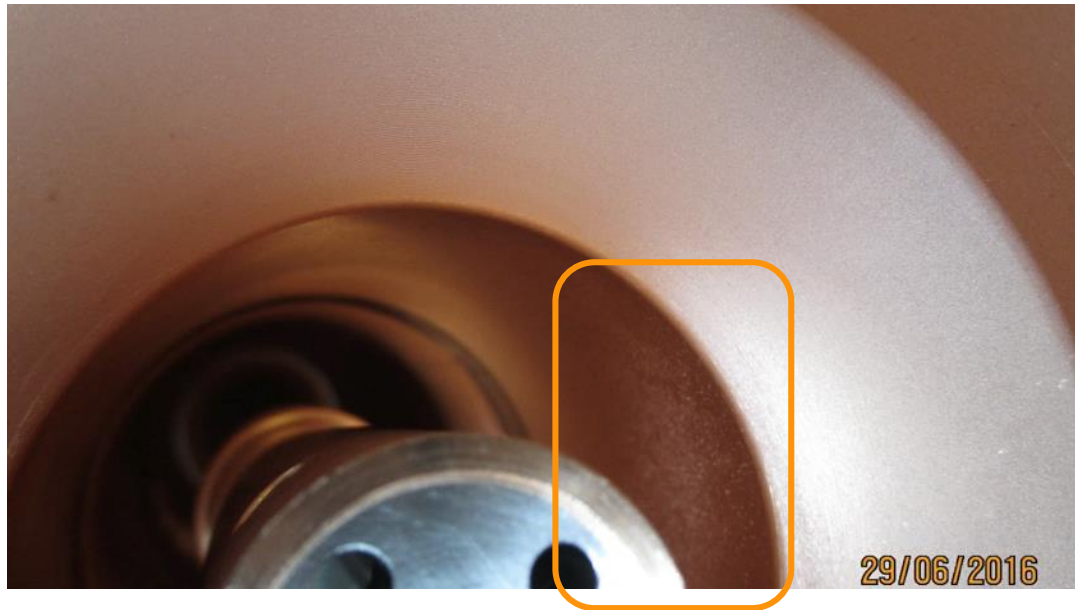


Denis Kostin, MHF-sl, DESY

Troubles on the track: Overheating during RF test



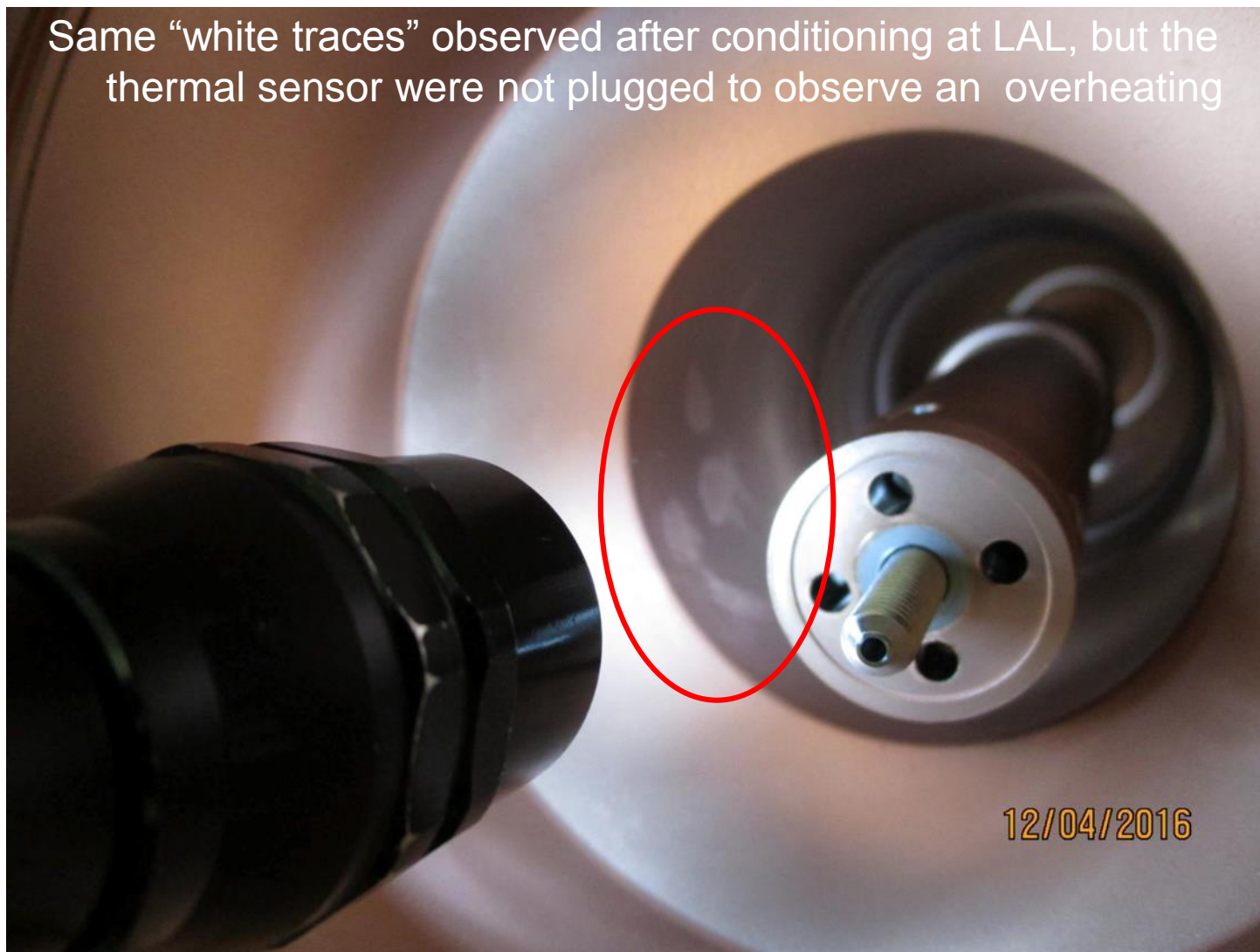
WPs inspection after observed Overheating in module testes



Troubles on the track: Overheating during RF test



Same “white traces” observed after conditioning at LAL, but the thermal sensor were not plugged to observe an overheating



Troubles on the track: Overheating during RF test



VNC Viewer
on 5.0 du 06/06/2014

Alimentations Alarms Modulateur HT Paramètres Station Conditionnement **Coupleurs XFEL** Graphes Graphes Temp. Interlock Image

Voix voie A

Num_P 41 Pic 394,2 kW Pch 427,9 kW Prc 16,3 kW

Pickup 0,5 1 1,7 8,9 4,8 0,4 V 8,5 A 8526,6 V

Vides 4,0E-8 1,9E-8 6,2E-7 mBar Vide Max 6,2E-7 A 6,2E-7 mBar

Valeurs max des x mesures Vide le 0,644

Raz Defaults Servitudes K

Alims ON
Défaut alim
Défaut Mo
Défaut Dét
Défaut Klys
Défaut Séc
Défaut Te
Défaut liais
Défaut Cou

Niveau_RF -30,0

STOP SU

White circular spots
Cu lack?

20/03/2016

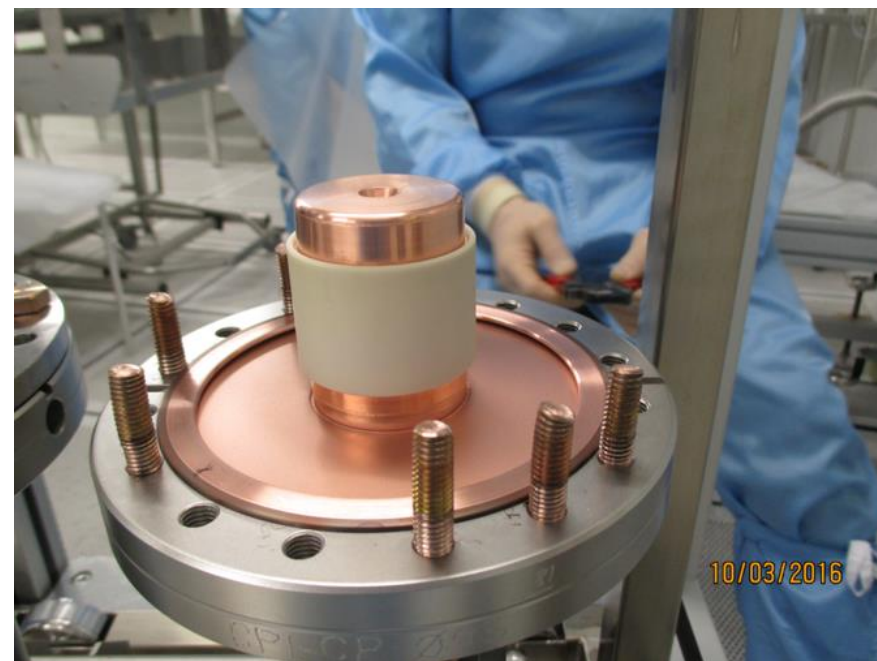
High pick-up signal le1C2 (near the warm window). Increasing during the time.

Vacuum level at the threshold limit

Power level blocked around 400 kW for hours (limiting vacuum) & even decrease.

Step 5
Step 7

Troubles on the track: Other minor issue



First, we faced difficulties to remove the WP because of the tilted threaded rods, blocked in the flange.

Troubles on the track: Other minor issue



The 7 rods were then removed with a pliers, with the risk to heat the cold ceramic in case of bad handling, and to contaminate the parts with metallic particles.

Troubles on the track: Other minor issue

Once the rods removed, we started to rework the tapped holes. However, the quality of the original thread was so bad, that the tool was broken inside one hole.





Thanks for your attention.