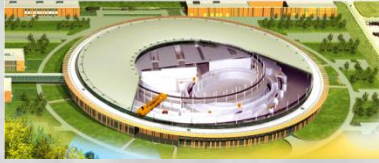


19th European Synchrotron Light Source Radio-Frequency Meeting

September 30th – October 1st, 2015

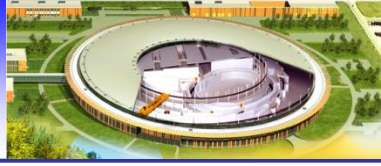
MAX IV, Lund

NEWS ABOUT THE SOLEIL RF SYSTEMS

Operational results, upgrades, R&D's

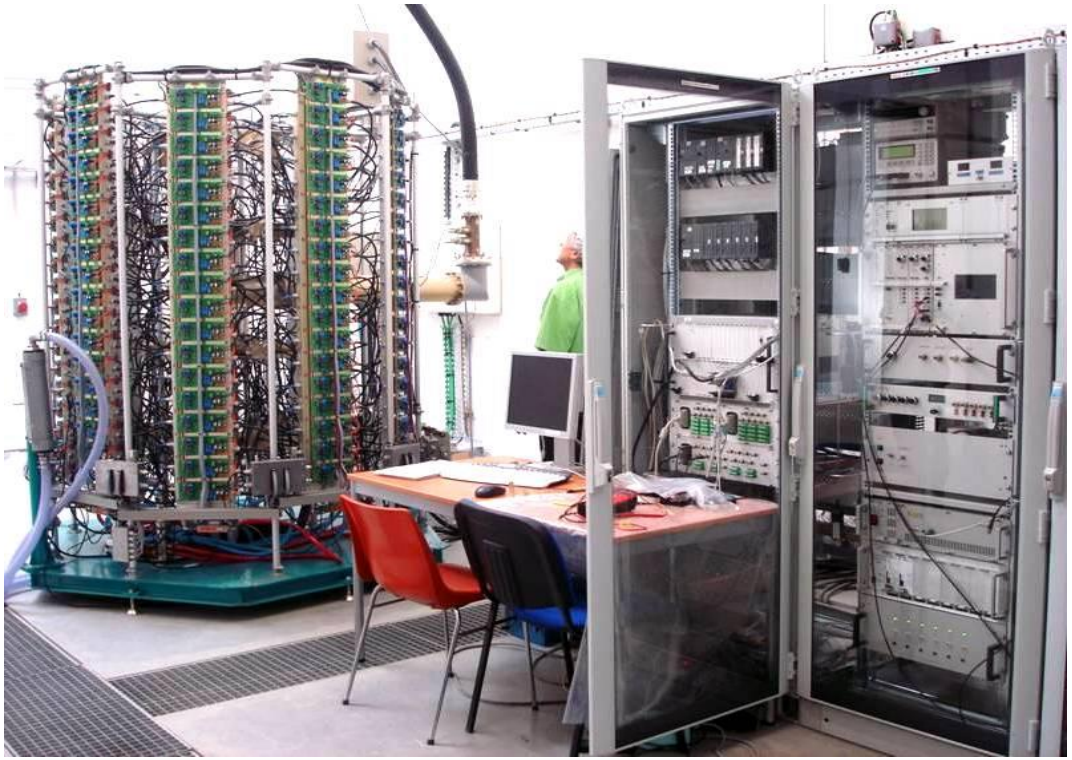
P. MARCHAND

SOLEIL Booster RF system



- E_n : 100 MeV → 2.75 GeV (rep. 3 Hz) ; V_{RF} : 0.2 → 1 MV @ 352 MHz
- 1 x 5-cell Cu cavity (CERN LEP) → P_{tot} : 25 kW (P_{dis} : 20 kW, P_{beam} : 5 kW)
- 1 x solid state amplifier (SSA) → 35 kW CW @ 352 MHz (developed in house)

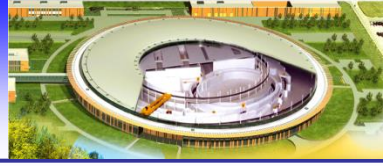
Cavity in the BO ring



BO RF room (amplifier with LLRF & control)

≈ 50 000 running hours over 9 years and only a single trip in operation, due to a human mistake
The 35 kW SSA (≈ 150 RF modules of 300 W) still exhibits 100% operational availability
≈ 1 module failure / year, without impact on the operation, thanks to modularity & redundancy

Booster RF upgrade plan



- The objective is to improve the ***injection efficiency in the low-α operation*** mode by a factor of ~ 2 for radiation safety reasons
- That requires increasing V_{RF} ***from 1 MV up to 3 MV*** in order to achieve the proper bunch length

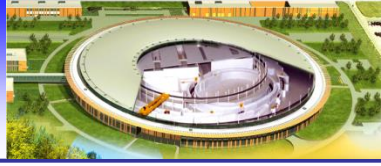
⇩

- **Install our available spare cavity into the BO ring** & power it with 60 kW (V_{RF} = 1.8 MV) → **Need to build a new 352 MHz SSA (~ 100 RF modules of 600 W) + LLRF & Control**
- **Increase V_{RF} of the existing plant from 1 MV up to 1.2 MV** → P_{RF} ~ 30 kW (P_{beam} ~ 0)
- **There is free space for accommodating the 2nd cavity in one straight section of the ring and a 60 kW SSA on the ring roof → Infrastructure work**
- **Additional benefits : power savings or redundancy in all the other modes of operation**

⇩

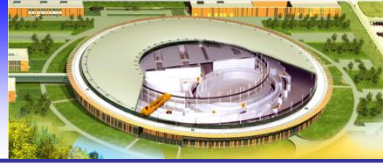
Under study for budgeting in 2016 and commissioning in 2017

SOLEIL SR RF system



- **E_n = 2.75 GeV, ΔE = 1.2 MeV, I_b = 500 mA**
  → P_{RF} = 600 kW & V_{RF} : 3 - 4 MV @ 352 MHz
- 2 cryomodules (CM), each containing a pair of single-cell s.c. cavities (Nb/Cu)
- Each of the 4 cavities is powered with a 180 kW solid state amplifier (SSA)
- Both CM's are supplied with LHe (4.2 K) from a single cryogenic plant

SR RF system operational results



Beam downtime caused by failures from the SR RF over ~ 50 000 running hours in ~ 9 years

Equipment	Downtime	Comments
a) 4 x RF amplifiers	~ $1\ 10^{-4}$	~ 5 h in 5 short events due to **preamplifiers** & power combiner ; **MTBF > 1.5 years** (cumulated by 4 ampli)
b) 4 x 500 kVA PS (230 Vac / 270 Vdc)	~ $3\ 10^{-4}$	~ 15 h in 4 faults from **PS control**
a) + b) = 4 x RF transmitters *	~ $4\ 10^{-4}$ *	MTBF ~ 1 year
c) 2 x CM's (4 cavities)	~ $3\ 10^{-4}$	Tuners, couplers, monitoring pick-ups, vacuum gauges
d) 4 x LLRF & control systems	~ $5\ 10^{-4}$	**Wrong interlocks** from noise (→ filtering & grounding)
a) + b) + c) + d) = 4 x RF systems	~ $1.2\ 10^{-3}$	MTBF ~ 2 000 h
e) 1 x Cryo-plant †	~ $1.8\ 10^{-3}$	~ 80 h in 5 evts (60 h from a single one) → 2nd compressor MTBF > 1.5 year ↔ relatively long recovery time †
Complete SR RF system	~ $3\ 10^{-3}$	→ ~ 6 % of the overall machine downtime (~ 5 %)

*** Expected << $1\ 10^{-4}$ with new generation of transistors (50 V) and PS (ac-dc converters in 2 kW modules)**

† **Cryogenics** recovery time reduced from 6 down to 3 hours by improving the process control → it does not affect anymore machine restart time, after utility failures; gain of another fact. 2 expected from **further upgrade plans:**

- Installation of a 3rd 50 m^3 GHe capacitor
- Modifications on the water cooling circuit
- Revamping of the control system and process

⇨ **Recovery time ~ 1.5 h, autonomy of ~ 5 hours with automatic restart & full compressor redundancy**

Activities on SSA's

Upgrade of the SOLEIL 180 kW - 352 MHz SSA's

- Excellent operational avaibility and MTBF, but still significant nb of module failures (2-3 % a year)
  → Matter of maintenance (~ 5 k€ mat. + 3 men.week / year) ; not so bad but still perfectible
- « Low cost » upgrade : replace LR301 transistors (28 V) by BLF574XR (50 V) + « module retuning »
  → Electrical power savings from the efficiency gain compensate the investment cost in ~ 3 years
  + More robust transistor & lower thermal stress → much less module failures → less maintenance
  + Higher power capability (max P_{mod} : 310 W → 450 W) → 500 mA with 3 amplifiers running
- 160 pre-amp modules of 1st and 2nd stages (2013) ; 1st tower (Aug. 2014) ; 2nd one (April 2015); next one (Oct. 2015) → go on at a rate of 1 - 2 towers a year
- Not a single failure of a « new » transistor

500 MHz SSA's

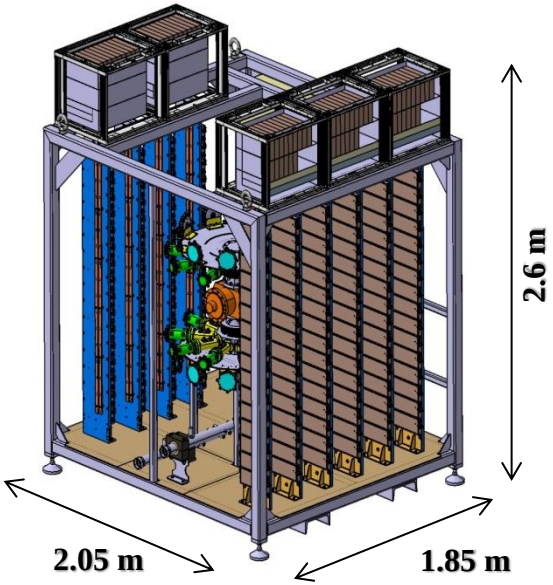
- 1 x 50 kW for ThomX completed
- 4 x 80 kW for SESAME under fabrication
  1st one by SOLEIL, 3 other ones by Sigmaphi Electronics, the SOLEIL licensee
- SOLEIL RF modules are used for SIRIUS

R&D @ 1.3 GHz for LUCRECE → LUNEX5

→ LDMOS vs GaN transistor

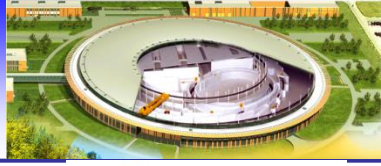
→ R. Lopes' talk about SSA's

50 kW SSA for ThomX

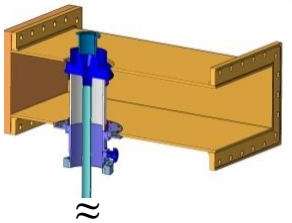


80 kW SSA for SESAME

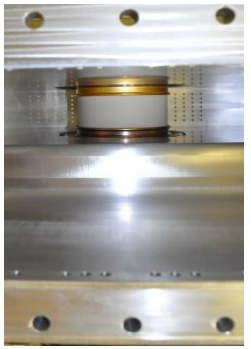
Input power coupler (IPC) upgrade

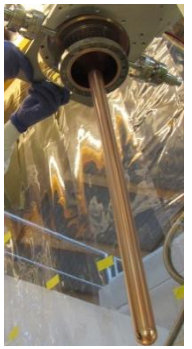


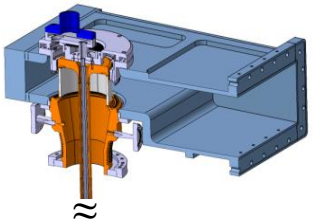
- Original SOLEIL IPC is a LEP2 type antenna → 200 kW CW @ 352 MHz
- Problems of ceramic aging with LEP type IPC's at ESRF
- *300 kW / cav* → SOLEIL can store 500 mA using a single CM → redundancy



In 2011, collaboration agreement with CERN & ESRF in order to develop a new 352 MHz version of IPC, based on the LHC design (at 400 MHz) and capable of handling *up to 300 kW*

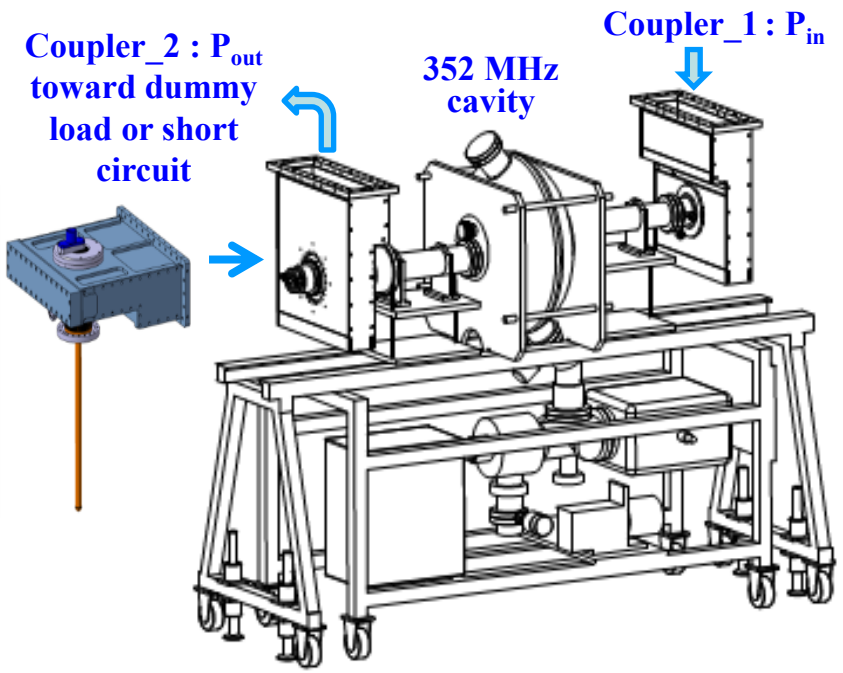




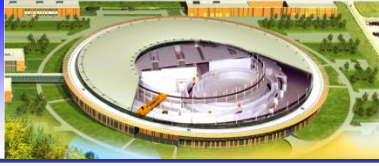


April 2013, the 1st pair of upgraded IPC's, built at CERN for SOLEIL, was successfully conditioned with RF power *in the ESRF test-stand*, using a Cu cavity from CERN :

- 300 kW CW *transmitted* through each IPC into a water cooled dummy load
- *In full reflection* on a short circuit plate 200 kW CW & 365 kW in 160 µs pulses



New IPC implementation



August 2013, one of the two pre-conditioned IPC's is mounted on CM1, *in situ*, without removing it out of the ring, using a hood with laminar air flow, enclosed within a plastic tent & a slight N_2 gas overpressure inside the cavity

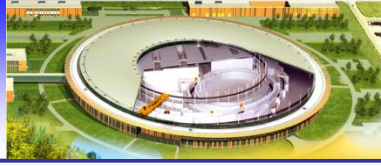
→ *"Clean room" built on top of the CM !*

☺ **After only few days of RF conditioning the cavity could provide up to 1.5 MV with 150 kW CW in full reflection and end of August 2013, when restarting the SOLEIL operation, we could quickly store up to 500 mA without any trouble**

☹ **After ~ one week of operation, "some vacuum activity (multipacting)" on the new IPC at P ~ 110 kW, which sometimes triggered vacuum interlocks → In user runs, operation below 110 kW, compensating with the other cavities**

☹ ☹ **In spite of several re-conditionings during the next shutdowns, the same scenario repeated itself several times : no problem at the beginning of the following run, then a kind of "de-conditioning" after a couple of weeks**

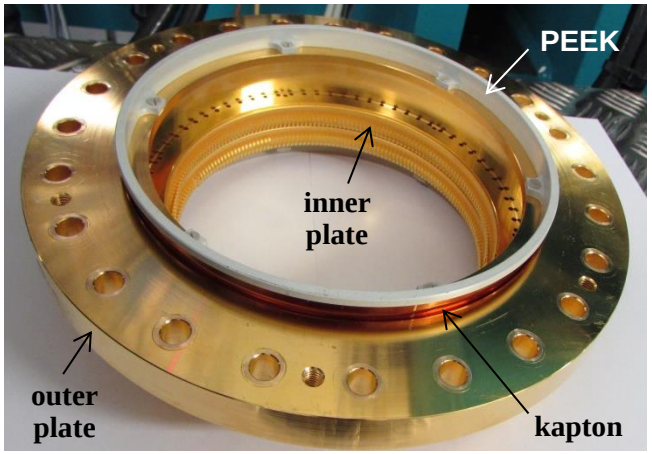
IPC multipacting cure

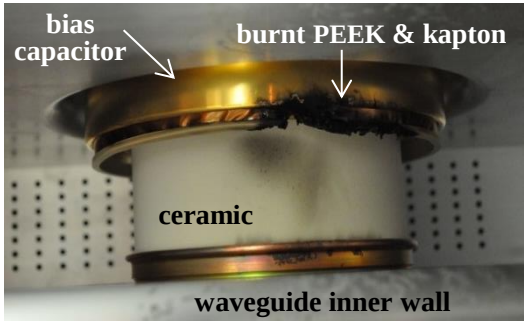


Shutdown of April 2014 : implementation of a " *bias capacitor* " for generating a bias dc - field at the ceramic window location, aimed at destroying multipacting resonant conditions

The multipacting indeed fully disappears when applying a dc voltage of ~ 1 kV and it remained ok in operation

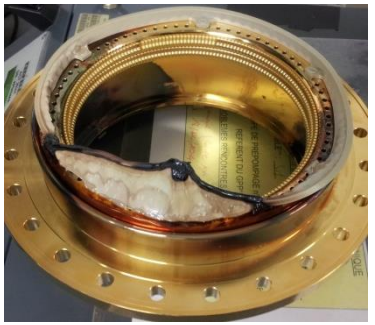
Shutdown of Aug. 2014 : replacement of the 2nd IPC of CM1 following the same way than the 1st one (+ bias capacitor)
→ Machine restart and following runs ok ☺ ☺ ✌





Nov - Dec 2014 : 2nd pair of IPC's + bias capacitors tested at ESRF
Couplers themselves ok : conditioned up to more than 300 kW
But bias capacitors damaged by overheating → Ceramic dirtying
→ Restored by sand blasting

😯 **!! ??**

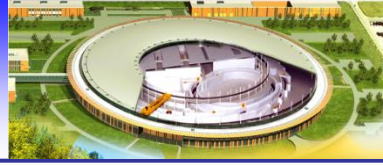


Shutdown of Dec 2014 : inspect bias capacitors in use on CM1 couplers → Strongly damaged by overheating
And it was still working !!??

New EM simulations pointed out errors of dimensioning
→ Beg. 2015, bias capacitors of CM1 replaced + proper temperature controls → Since then ok ☺

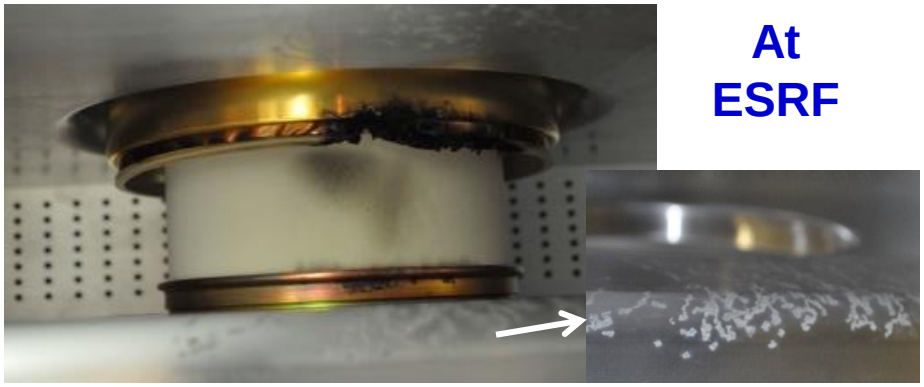
Another pair of couplers presently under test at ESRF → Mounting on CM2 scheduled for 2016

IPC arcing (air side)

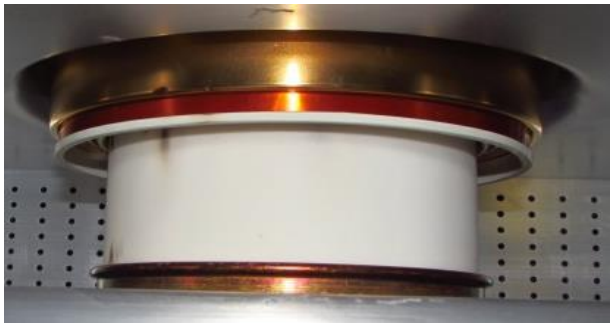


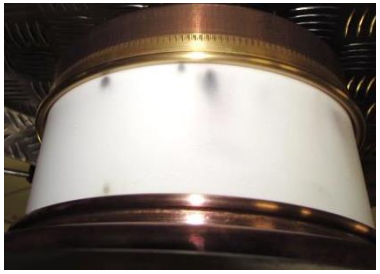
It happened once during the test at ESRF with damaged bias capacitor and once at SOLEIL when restarting after the exchange of a bias capacitor (likely the introduction of a small metal piece)
In both cases the coupler ceramic and its Cu lips were restored by sand blasting

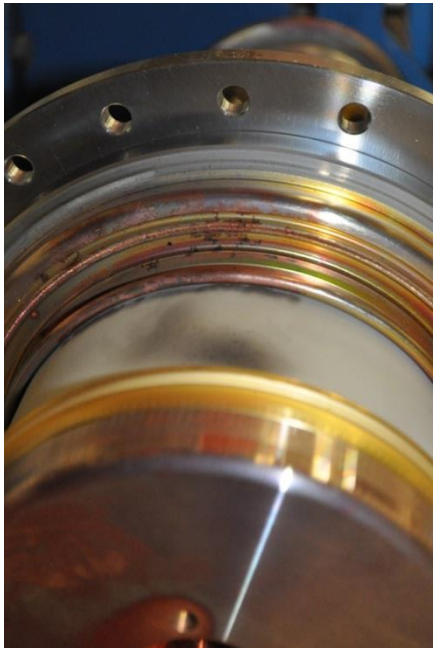
At ESRF

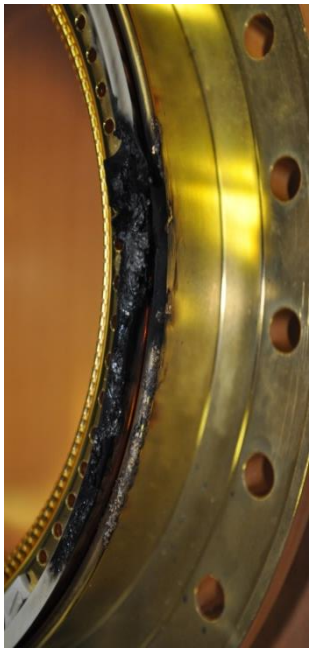


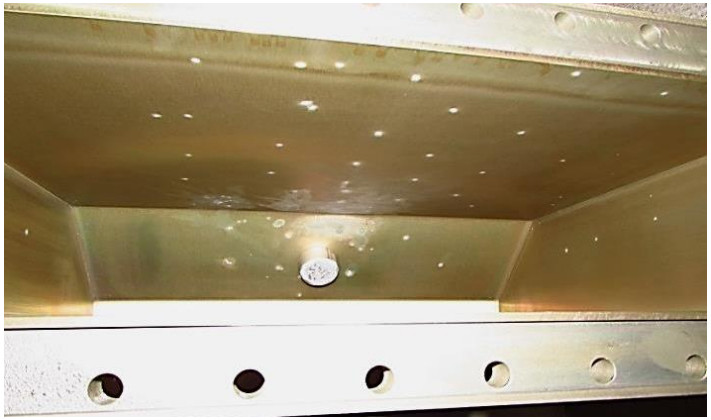
At SOLEIL



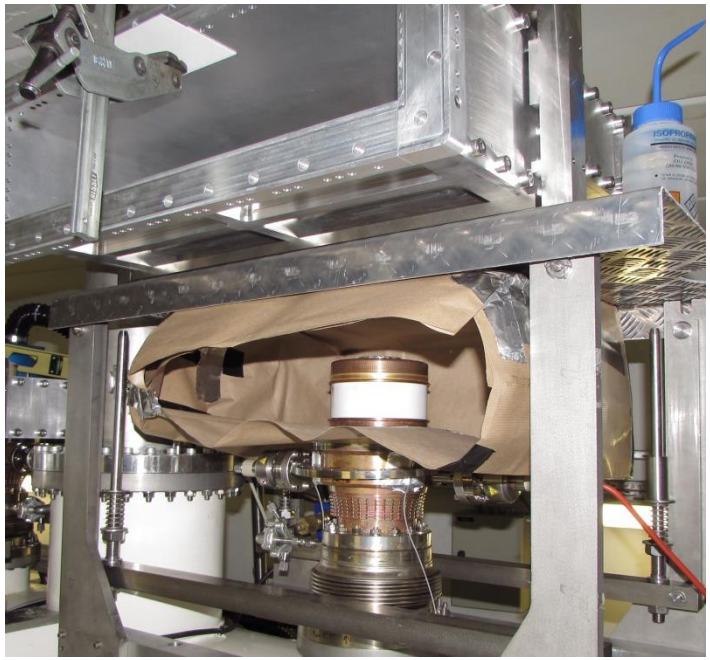


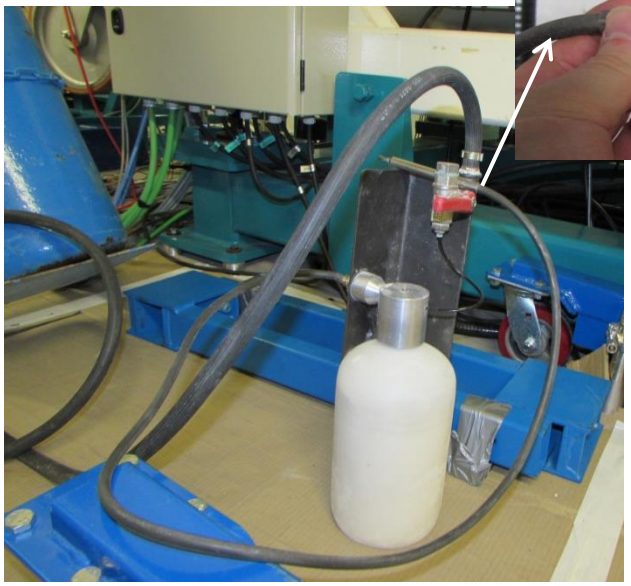


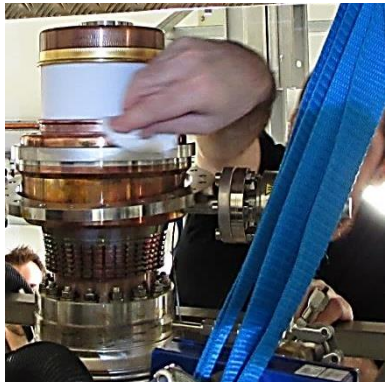


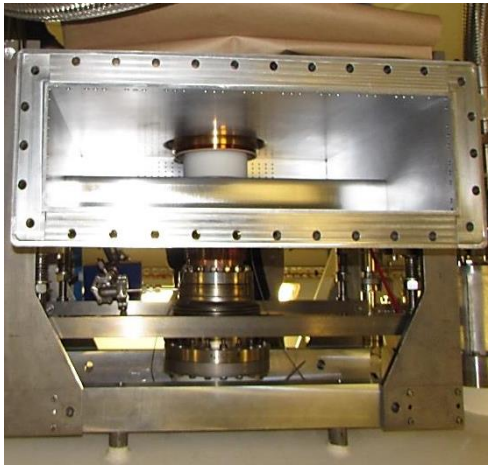


Sand blasting of the IPC ceramic









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