XFEL Coupler Cleanliness Issues

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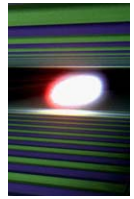
Review of SPL RF Power Couplers, March 16-17 2010

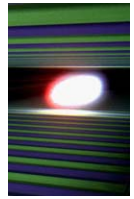
1. Power Coupler Specification



Frequency	1.3 GHz
Peak power (incl. control margin)	150 kW
Repetition rate	10 Hz
Pulsed mode	500 µsec risetime, 800 µsec flat top with beam
Average power	1.9 kW
High Power Processing (only on module test stand)	1 MW at reduced pulse length (≤500 µsec and repetition rate 1 Hz)

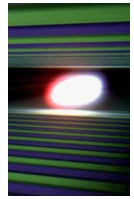
Coupling	$Q_{ext} = 10^6 – 10^7$ (± 10 mm)
2 K heat load	0.06 W
4 K heat load	0.5 W
70 K heat load	6 W
Lateral displacement	± 2 mm
diagnostic	sufficient for safe operation and monitoring

2. Power Coupler Design Criteria



- coax is easy for: - variable coupling
  - fabrication
  - assembly
- two windows for: - clean assembly of the cavity
  - save operation
- cold coax: - at 70 Ohm, 40 mm diameter
- warm coax: - at 50 Ohm, 60 mm diameter
- bias on inner conductor: - suppress multipacting
- flexibility: - bellows in the warm and cold coax
- ceramics: - Al_2O_3 with TiN coating
- copper plating: - 10/30 µm outer/inner coax
  - high thermal/electric conductivity (RRR ≥ 30)
  - high purity, Hydrogen free

2. Power Coupler Design Criteria, cont'd



Our coupler development requirements for cavity gradients > 25MV/m

- close the cavity vacuum as early as possible in a class 10 clean room
- protect the clean cavity surface during assembly of the coupler and cryostat

As a consequence

- two window design
- the cold window should be as close to the cavity as possible and separate from other parts
- coupler has to be cleaned to the standard of the sc cavity surface (usually by dust free water)
- vacuum parts separate from 'air parts'

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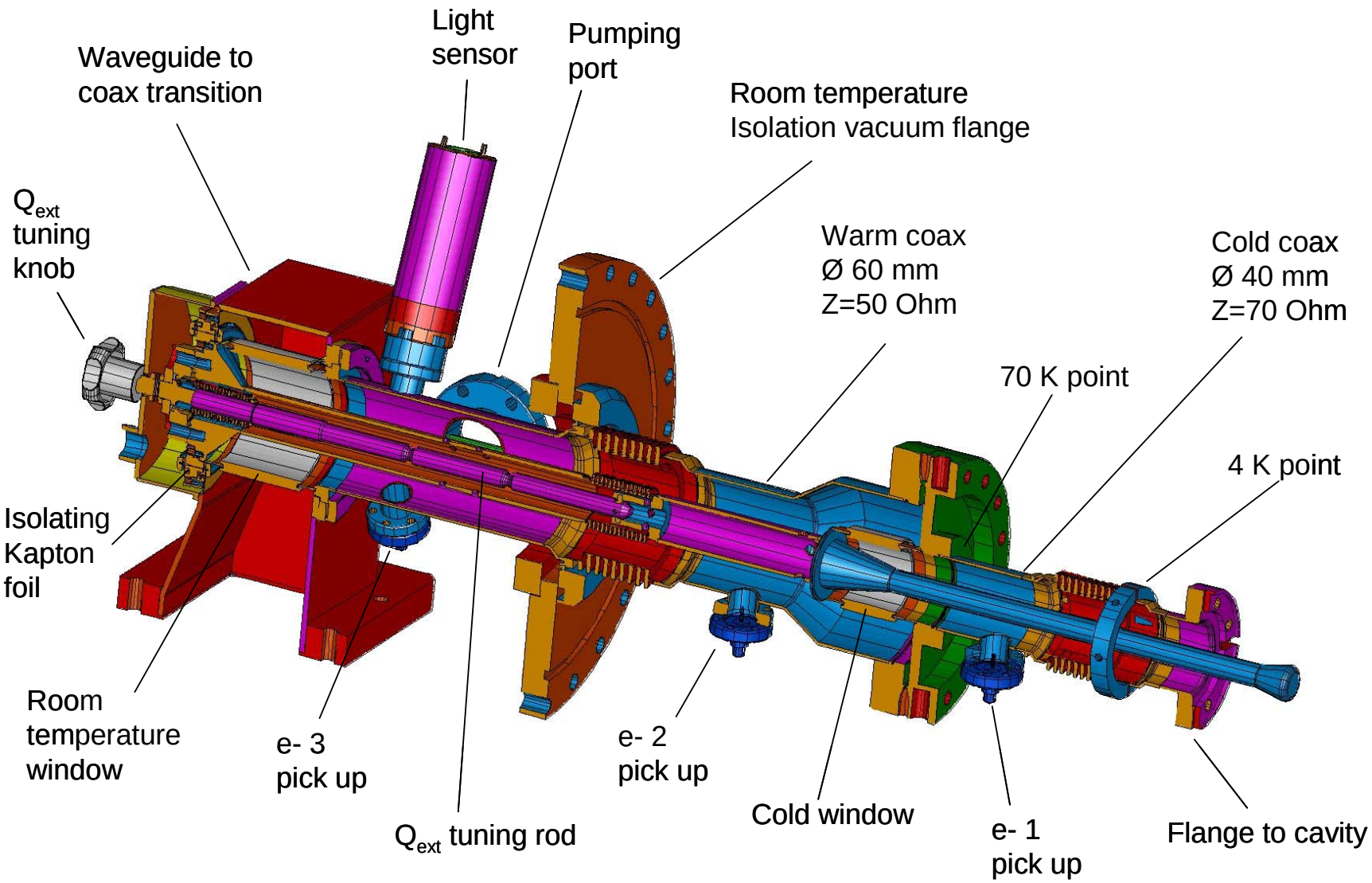
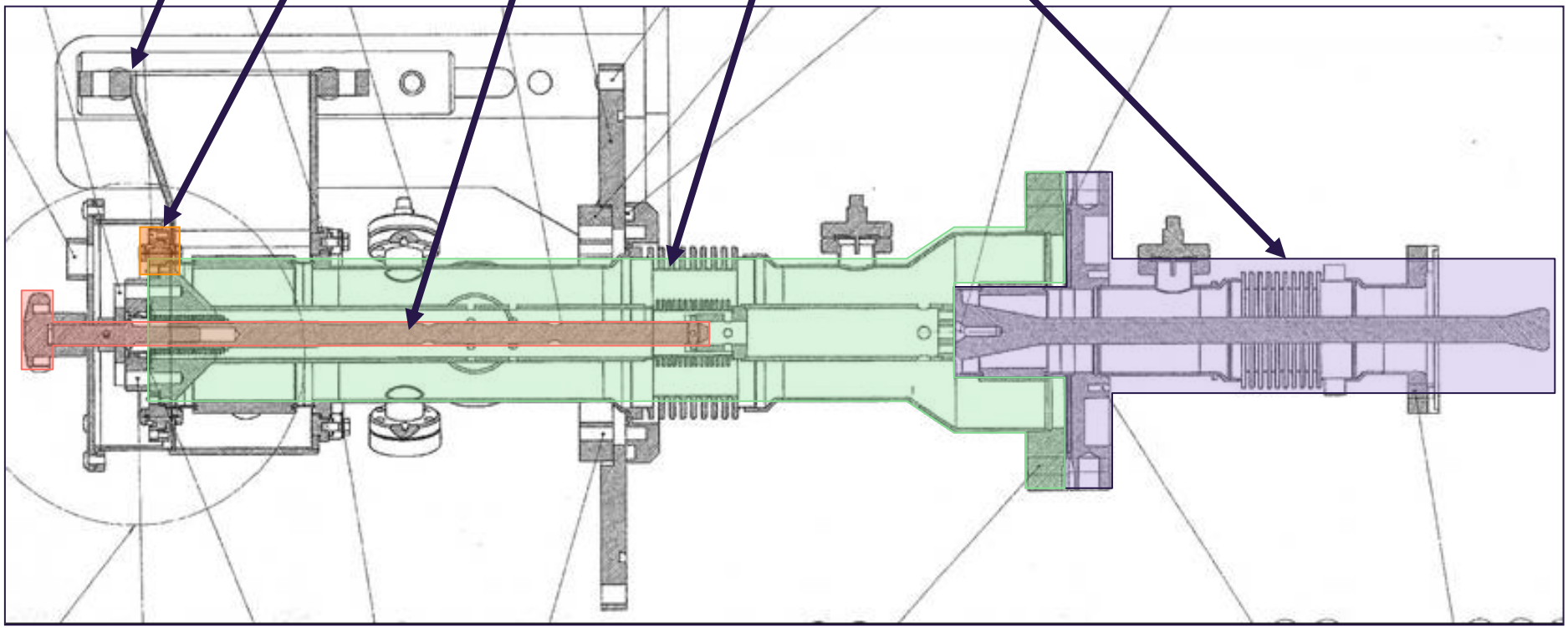
3. Power Coupler Design



4. Modularity

compatible coupler parts at XFEL coupler:

- WG, capacity, tuning rod, warm part, cold part



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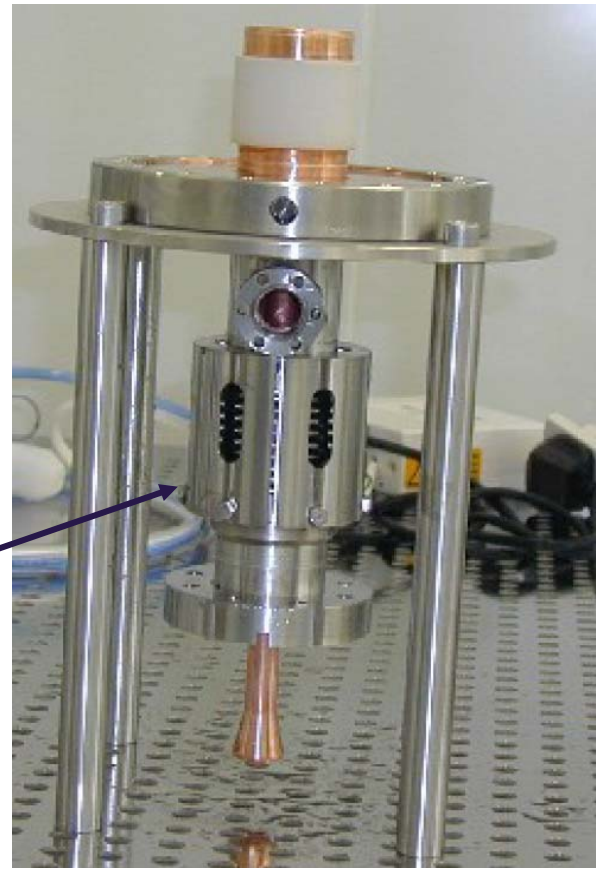
5. Cleanliness during fabrication

- clean fabricating area
- handling with no linty cotton (batiste) gloves only
- no scratches on RF surfaces
- no surface contamination with hydro carbons, grease, finger prints or dust
- intermediate storage of parts in N2 containers
- intermediate packing only in non polymeric bags (softener)

6. Coupler Cleaning Procedure

Cleaning steps of individual (vacuum) coupler parts:

- after copper coating all parts are baked at 400C for 2 h
- final weld to ceramic and leak check
- degrease in Tickopure at 50C for 15 min
- degreasing in dedicated bath
- rinse 6 times with ultra pure water
  (no detergent foam, resistivity > 14MOhm)
- blow dry with filtered dry ionized Nitrogen
- dry in class 10 clean room
  (best under dry N2)



cold part drying in class 10

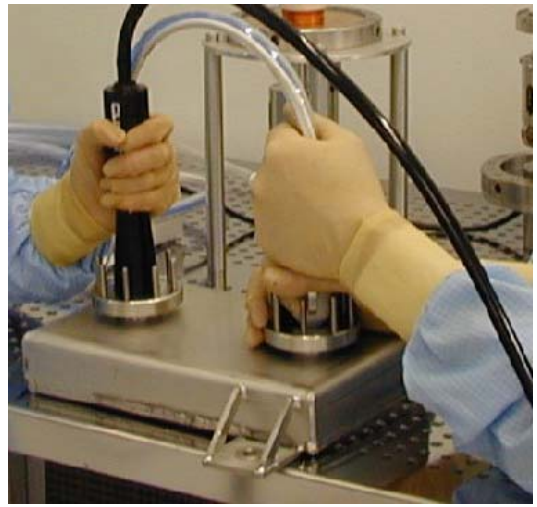
7. Particle check before test stand assembly

Blow with filtered and ionized nitrogen (P= 4 bars) on each cold parts :

- blowing on outer and measuring on opposite side
- blowing into CF16 port and measuring on the antenna
- blowing on the antenna and measuring on the CF16 port
- blowing on the antenna and measuring on the antenna

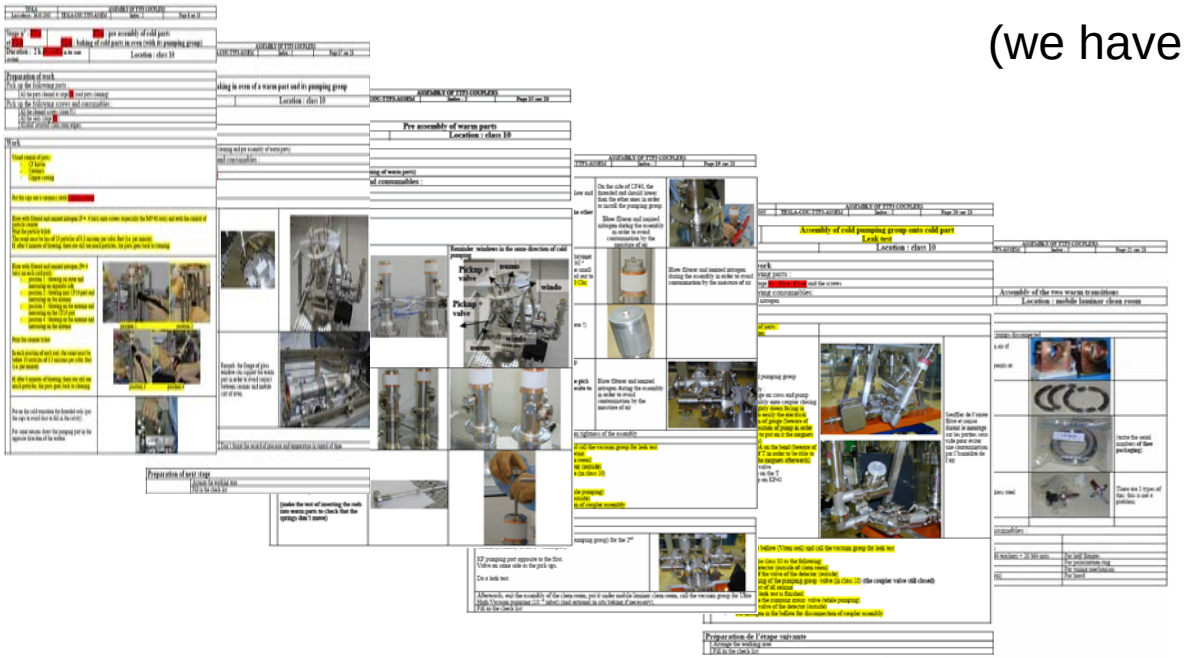
- Print the counter ticket
- In each position of each part, the count must be below 10 particles of 0.3 microns per cubic foot per minute)
- If, after 9 minutes of blowing, there are still too much particles, the parts goes back to cleaning.

- Same procedure with all coupler and test stand parts



8. Coupler assembling to the test stand

- follow the clean room rules
- take the particle count during assembly
- documentation of all assembly steps
- a detailed assembly instruction is important



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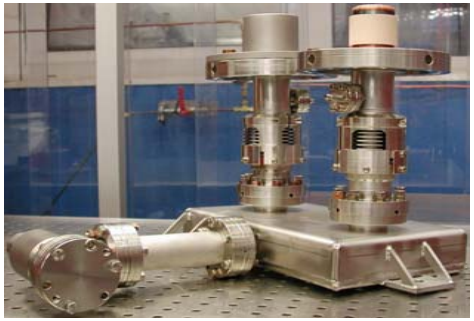
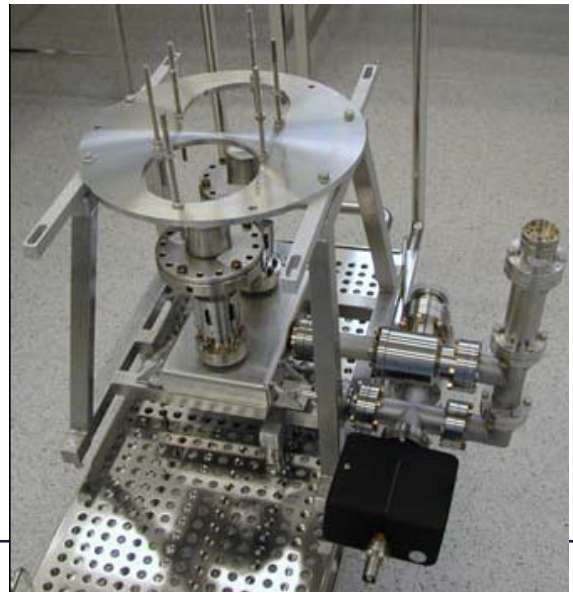
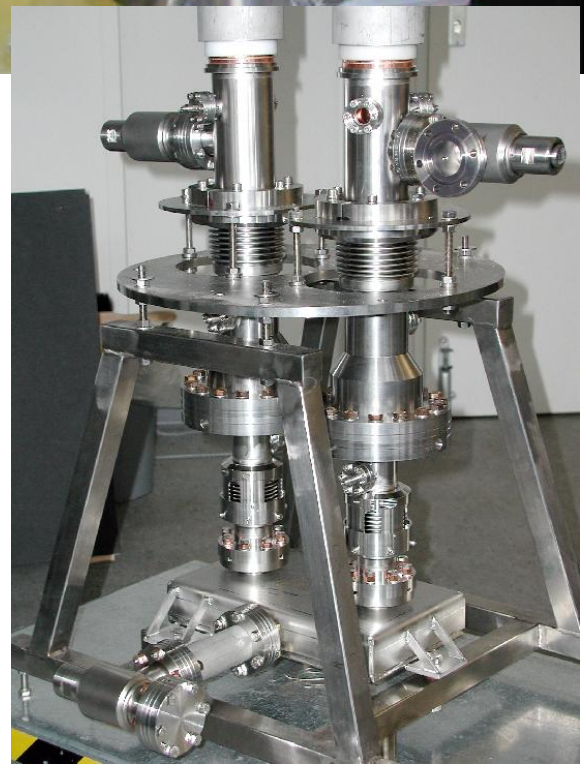
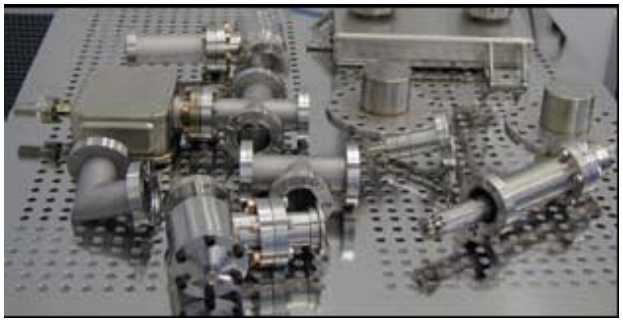
9. Test stand assembly at LAL







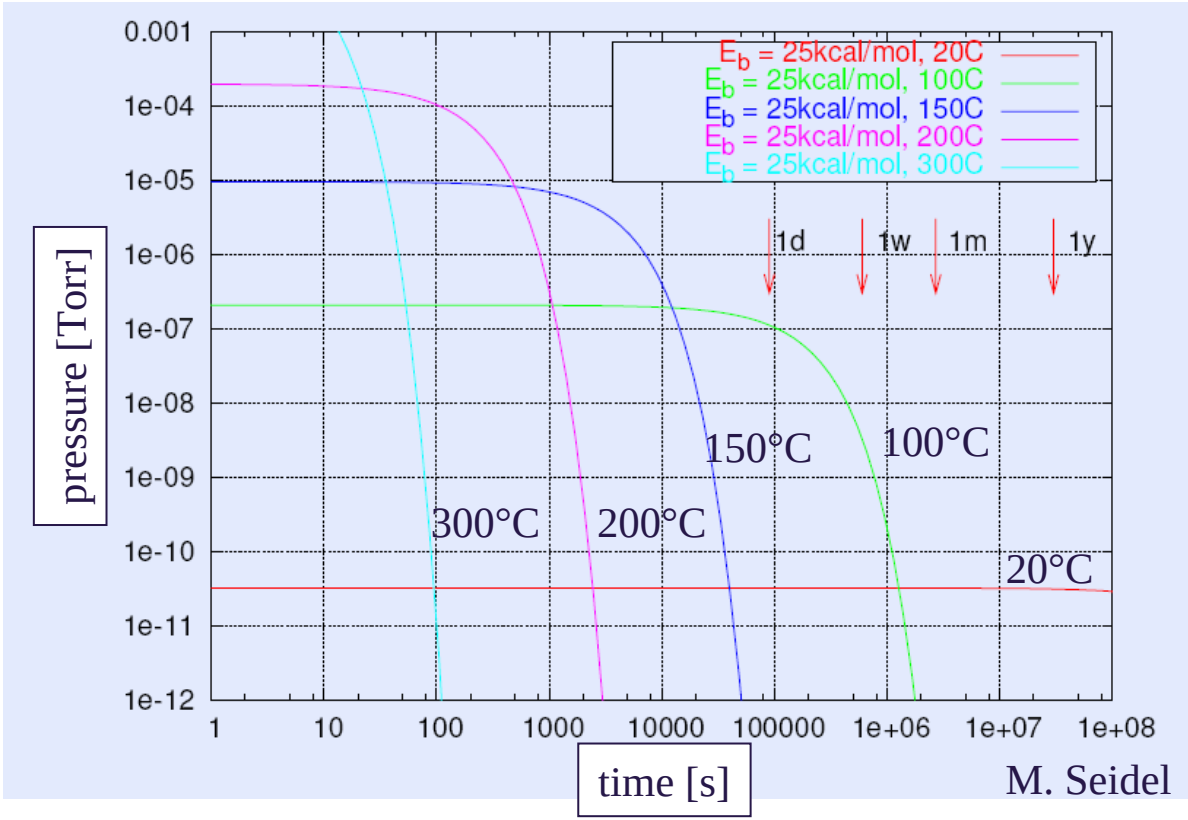


10. Backing on test stand

Backing accelerates the pumping time drastically

Simulation of the pumping time for different backing temperatures

(binding energy=25 kcal/mol,
A= 15000 cm2, S=15 l/s,
one monolayer)



11. Clean Handling after RF conditioning

Maintain the processing effect after RF conditioning.

warm parts:

- clean disassembly from test stand
  - store and transport under dry Nitrogen
  - avoid any contamination from dust, water, other (e.g. softener from plastic bags)

cold parts:

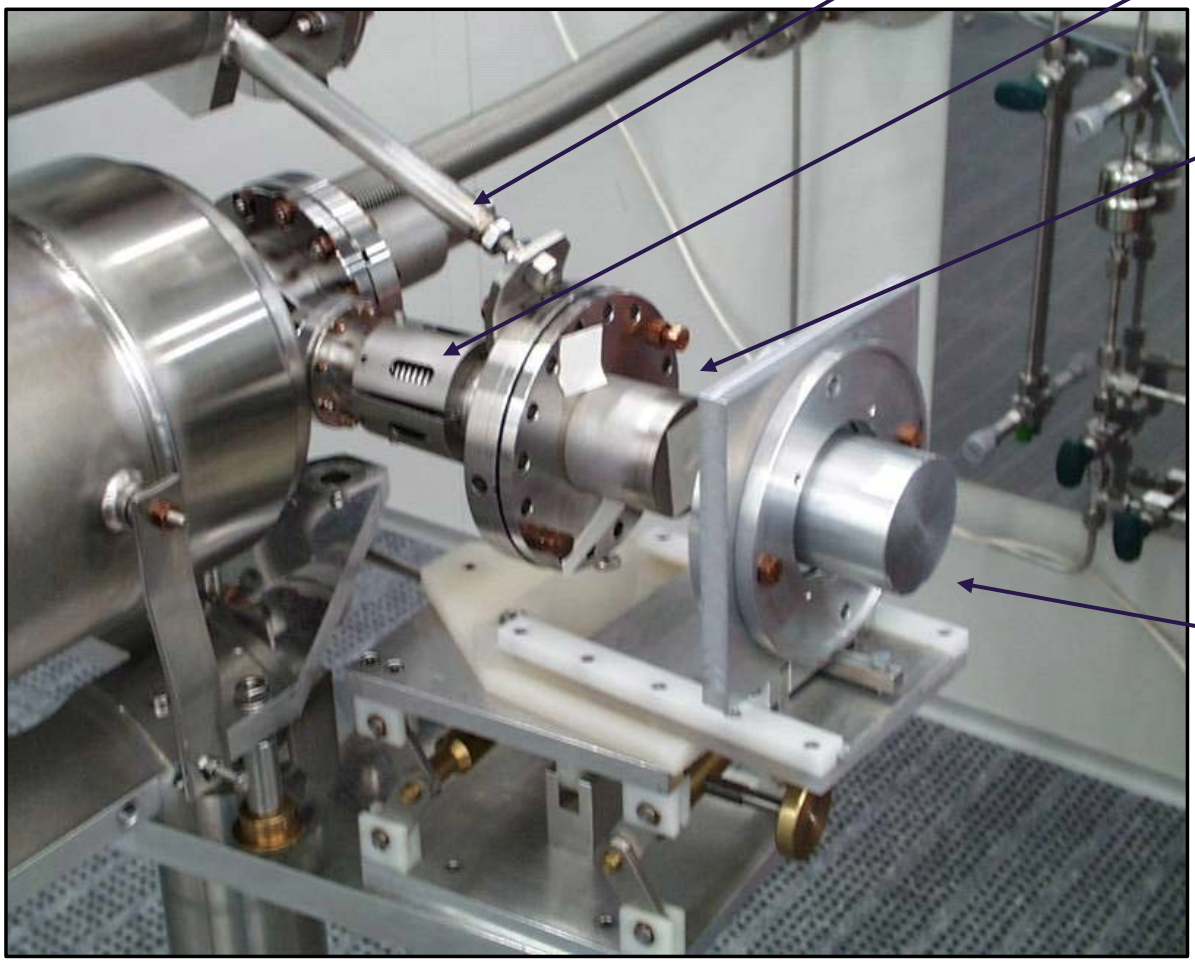
- stay on test wave guide under vacuum
- all RF surfaces are kept at dry Nitrogen atmosphere, caps on ceramics
- assembly to cavity in class 10 clean room directly from test stand

dry Nitrogen storage

sealing cap for cold window

12. Cold part assembly in clean room ISO4

coupler is supported by the rod and bellow clamp



cold ceramic is kept under dry Nitrogen and protected by a cup

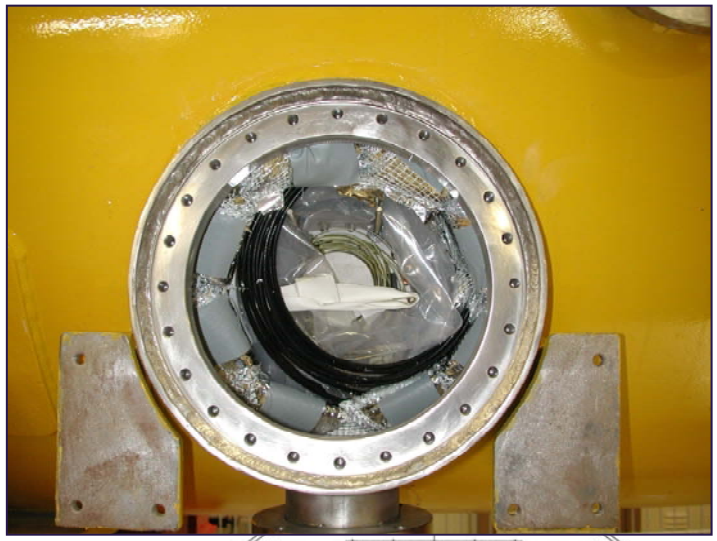
tool for safe and clean coupler assembly

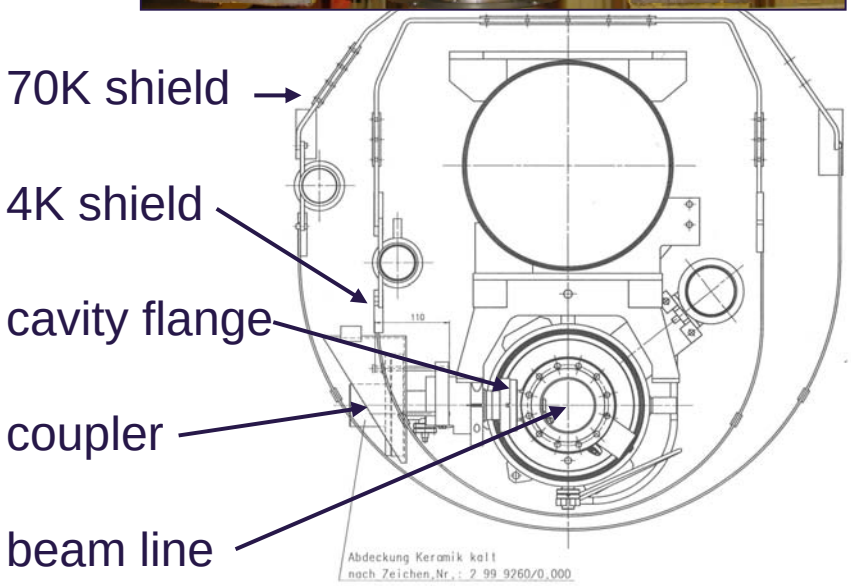
13. Warm Coupler Assembly on Module

clean assembly on module is difficult

- connecting flange of the coupler is inside the cryogenic tank with many sources of dust:
  - thermal shield with super insulation foil
  - cabling
  - other components

- class 10 inside the module is not possible

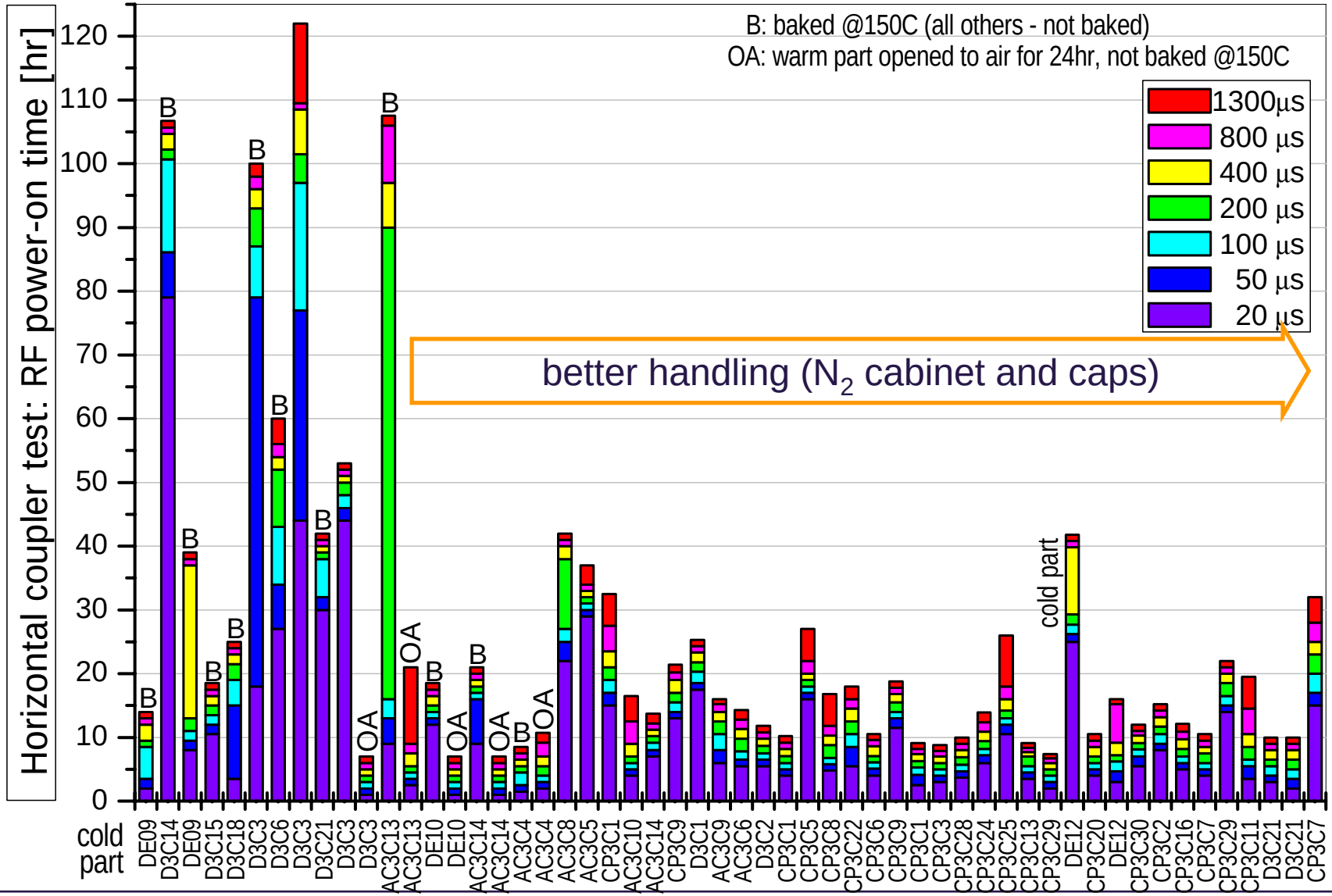




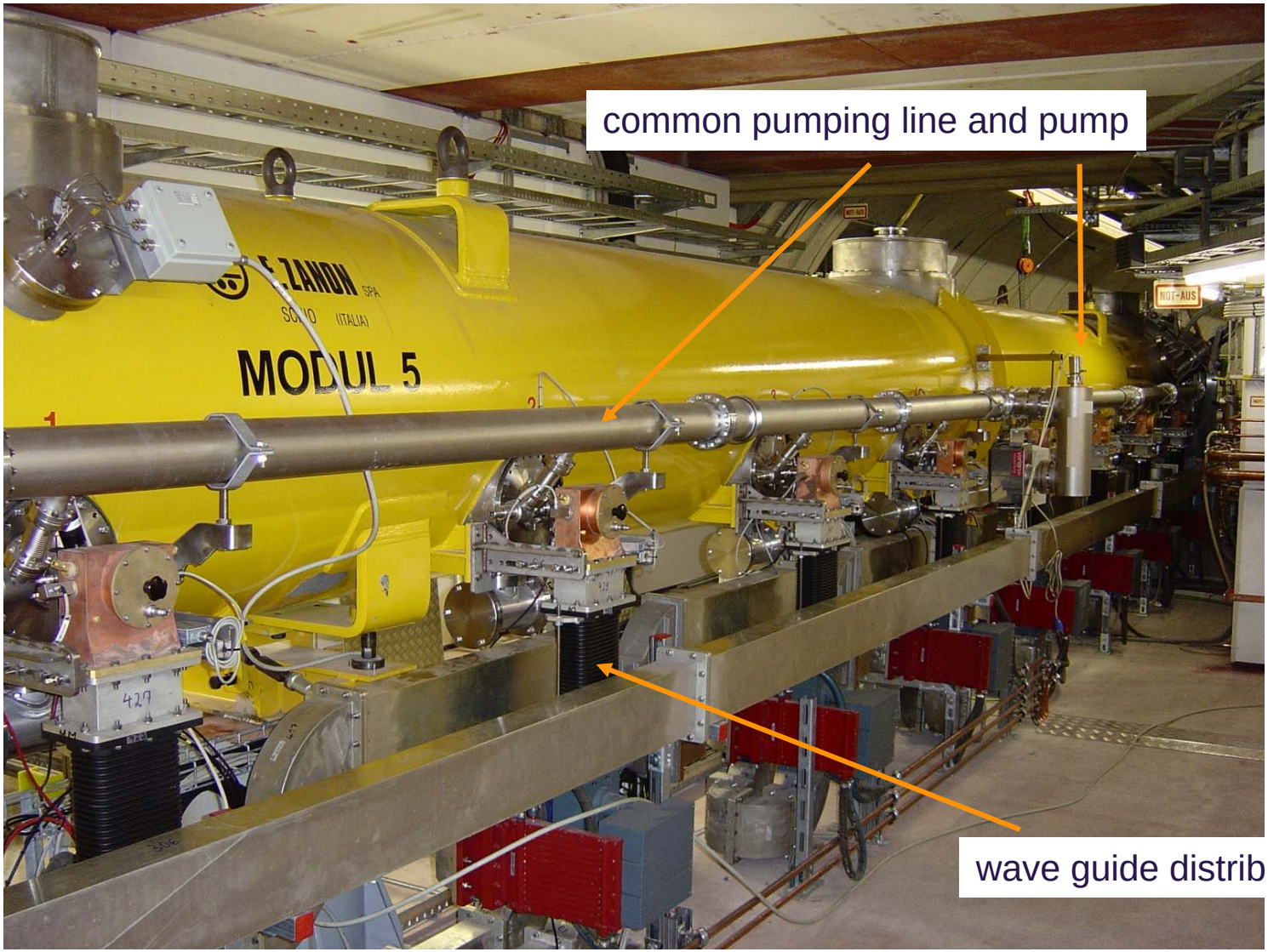
13. Warm Coupler Assembly on Module

- portable clean room
- blow dry and filtered Nitrogen through the coupler parts during assembly
- efficient tooling

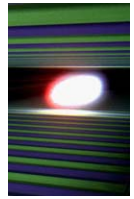
14. Conditioning times, horiz. cavity test, RT, full reflection



15. Power Coupler in FLASH on Module 5



A) Power Coupler Test and Operating Experience



- More than 60 TTF 3 couplers are tested on a coupler test stand at 1 MW, 2Hz, 1.3 ms, traveling wave, baked in situ, two at a time
- TTF 3 couplers are operated at the FLASH for more than 450 000 coupler-hours up to 400 kW, 2-10 Hz, 1.3 ms
- All couplers in the VUV FEL linac could be processed and operated up to the cavity performance limits

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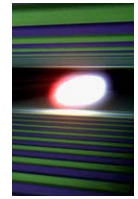
B) Power Coupler High Gradient Test



- An electro polished cavity & TTF3 coupler have been operated at 35 MV/m for more than 1100 hours in the horizontal test stand and also in FLASH with beam

- Forward power was above 600 kW

  (due to the not compensated Lorentz Force detuning)

- No degradation in the performance of cavity or coupler

  (During setup of LLRF system breakdowns in coupler and quenches in cavity were caused by unexpected high power pulses)