High Power Coupler Development for the ILC at KEK

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OUTLINE

1. Specifications for ILC input couplers
2. Developments of STF-couplers
3. Dynamic heat loads
4. Cu-plating
5. Coupler conditioning
6. Summary

Main Specifications of ILC Input Coupler in TDR (1)

- Frequency : 1.3 GHz
- Operation pulse width : 1.65 ms (???? 1.5 ms)
- Operation repetition rate : 5 Hz / 10 Hz
- Required RF power in operation : ~ 400 kW
- Range of external Q value : 1.~ 10. x 10^6 (tunable)
- Number of windows : 2
- Bias voltage capability : Required

Main Specifications of ILC Input Coupler in TDR (2)

- RF processing :

  in test stand (reflection mode), > 600 kW (1.6 ms)

  (transmission mode), ?? 2.4 MW ??, ave. 20 kW ??

  in cryomodule, > 1200 kW (< 400 μs)

  > 500 kW (> 400 μs)

- RF process time :

  in warm state, < 50 hours (?? How many couplers)

  in cold state, < 20 hours, ????

PAC Summary and Recommendations (ILC Project Advisory Committee, Dec., 2012)

- The Japanese power coupler appears to be a good design, and should be pursued further to be adaptable to the TESLA-type cavity,
  (having the smaller cold-end interface flange).

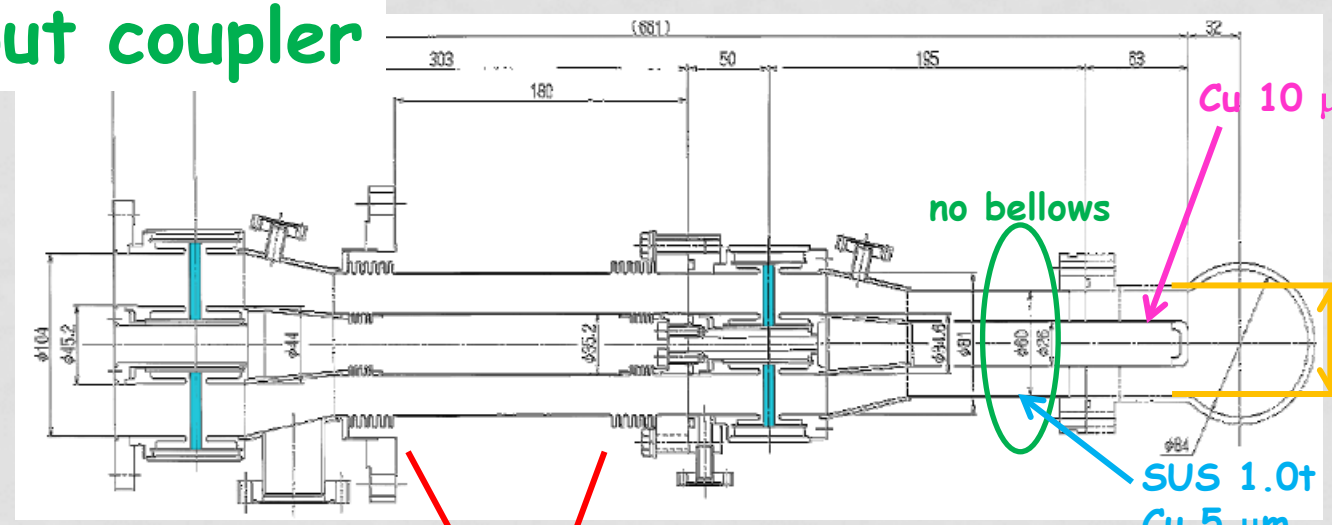
- My personal is

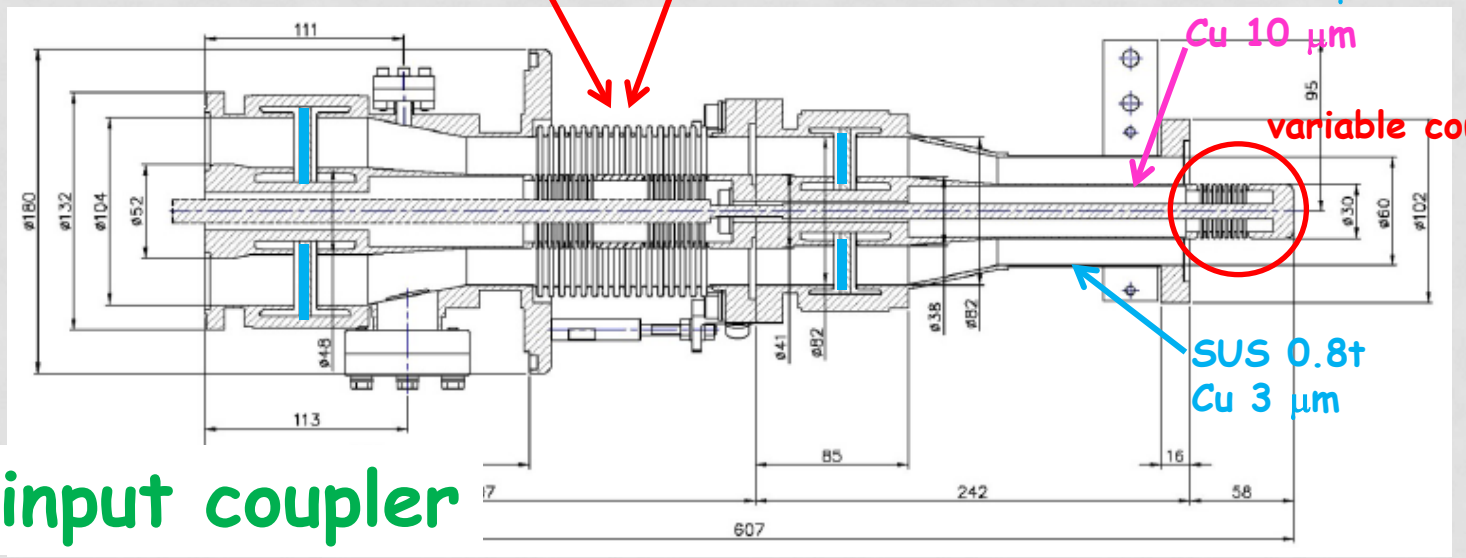
"TESLA-type cavity for ILC should have the larger cold-end interface flange to adapt the STF input coupler."

"What is the optimum cavity structure really suitable for ILC ?????"

STF-1, STF-2 Input Couplers

STF-1 input coupler

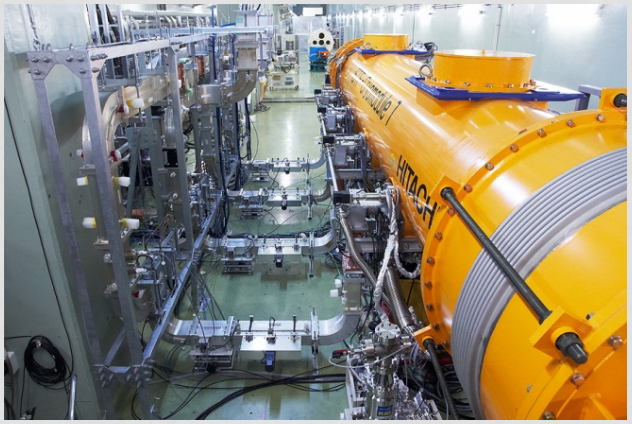




STF-2 input coupler

Cryomodule operation in STF

STF Phase-1
Four 9-cell cavities (2008')

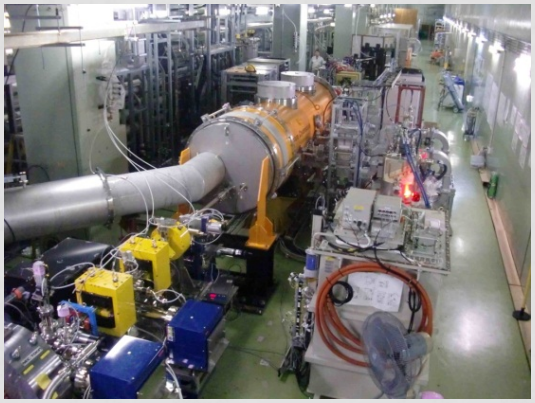


4 x STF-1 input couplers

S1-Global
(4+4) 9-cell cavities (2010')

4 x STF-2 input couplers

STF2 - Capture Cryomodule
Two 9-cell cavities (2011')



2 x STF-2' input couplers

STF2 – CM1&CM2a Cryomodule
(8+4) 9-cell cavities (2014')

12 x STF-2'' input couplers

Total 22 STF-2 input couplers were fabricated.

Comparison of coupler performance in S1-Global cryomodule

There was no severe problems in operation, but ……..

Further studies in STF-2 couplers

- Reduction of static loss
- Reduction of dynamic loss
- Efficient cooling by thermal anchor
- RRR of Cu-plating

Dynamic loss measurements in S1-G

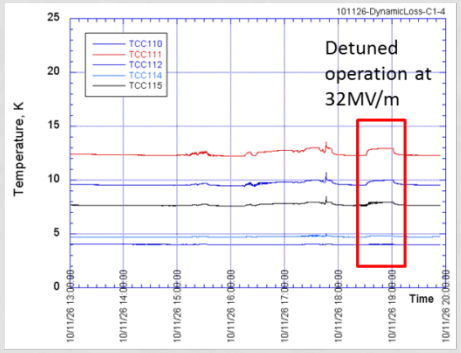
	TTF-III	TTF-III	STF-2	STF-2	STF-2	TTF-III	STF-2				
	C-4	C-1	A-3	A-2	A-2	4 C Cavities	4 A Cavities	4 C Cavities	4 A Cavities	7 Cavities	7 Cavities
Date	Nov. 17	Nov. 19	Nov. 23	Nov. 24	Nov. 25	Nov. 26	Nov. 30	Dec. 2	Dec. 3	Dec. 9	Dec. 10
Gradient	28 MV/m	25.2 MV/m	32.3 MV/m	38 MV/m	32 MV/m	32 MV/m Detune	32 MV/m Detune	20 .0 MV/m	26.9 MV/m	25.4 MV/m	20.4 MV/m
Dynamic Loss	0.84 W	1.44 W	2.8 W	4.8 W	2.6 W			2.7 W	6.9 W	9.6 W	4.8 W
Detuned Loss	0.09 W	0.18 W	0.7 W	1.8 W	1.2 W	0.5 W	4.6 W	0.2 W	2.5 W	2.6 W	1.6 W
Dynamic Loss at Cavity	0.75W	1.26 W	2.0 W	2.9 W	1.3 W			2.5 W	4.4 W	7.0 W	3.2 W
Q_0	8.8E9	4.3E9	4.3E9	4.2E9	6.5E9						
								C1=22.2 C2=18.9 C3=14.9 C4=24.3	A1=15.8 A2=37.6 A3=32.9 A4=21.4	C1=25.2 C2=NA C3=17.6 C4=28.8 A1=15.3 A2=37.4 A3=32.4 A4=20.9	C1=20.1 C2=NA C3=14.1 C4=23.0 A1=12.3 A2=30.4 A3=26.0 A4=16.7

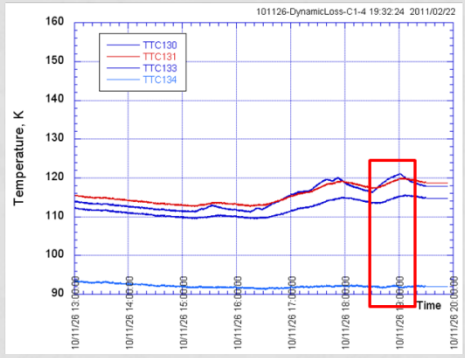
Dynamic losses of KEK couplers was 9 times larger than those of TTF-III couplers.

Temperature rises at input coupler

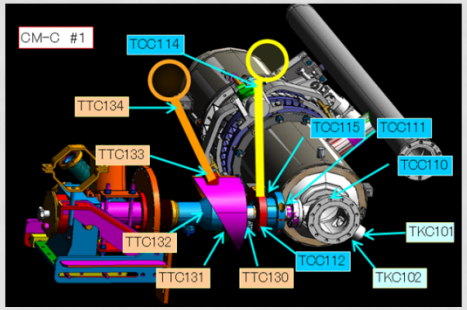
TTF-III input coupler

Temperature change during detuned 32MV/m
Module-C





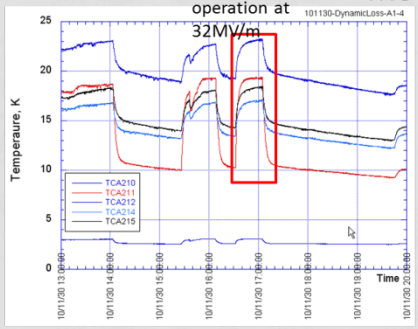
Cavity-C1

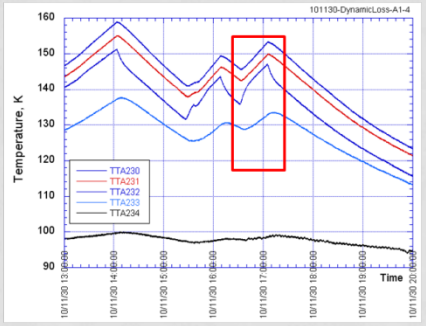


For 30 min. operation,
$\Delta T_{@TCC111}$=0.7K (12.3K->13.0K)
$\Delta T_{@TTC130}$=5K (116K->121K)

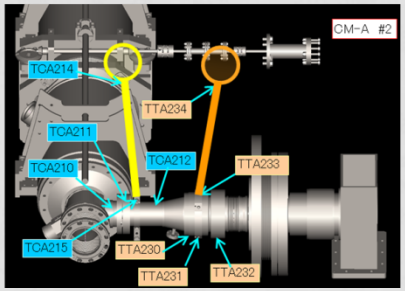
STF-2 input coupler

Temperature change during detuned 32MV/m
Module-A





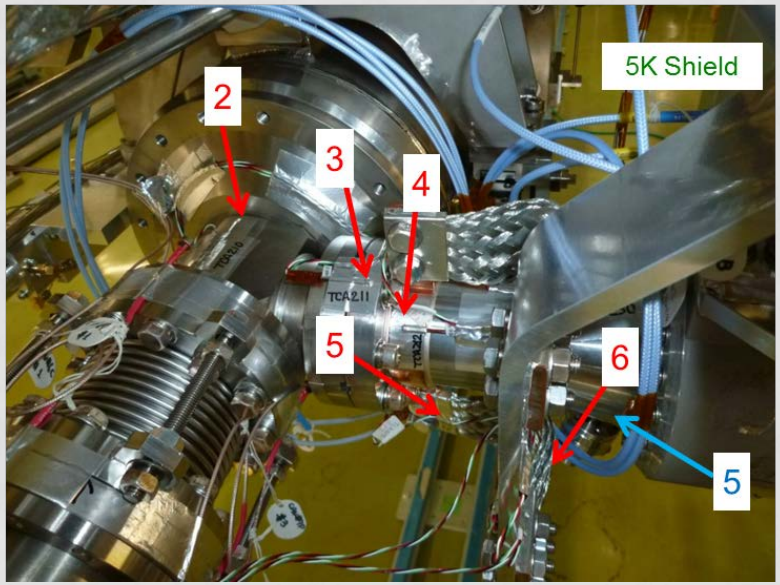
Cavity-A2



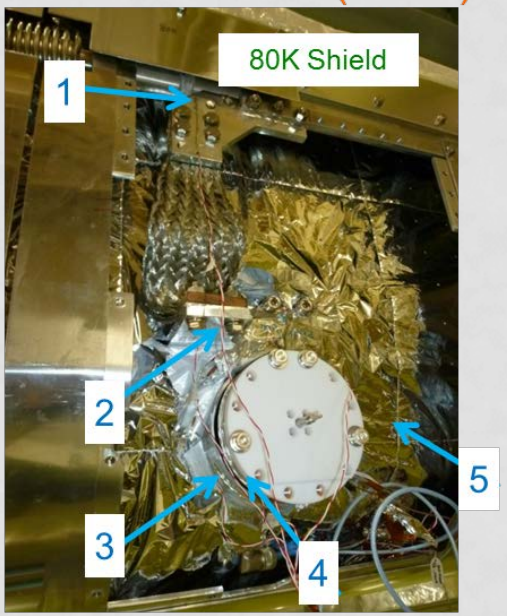
For 30 min. operation,
$\Delta T_{@TCA211}$=9K (10.3K->19.3K)
$\Delta T_{@TTA230}$=10K (137K->147K)

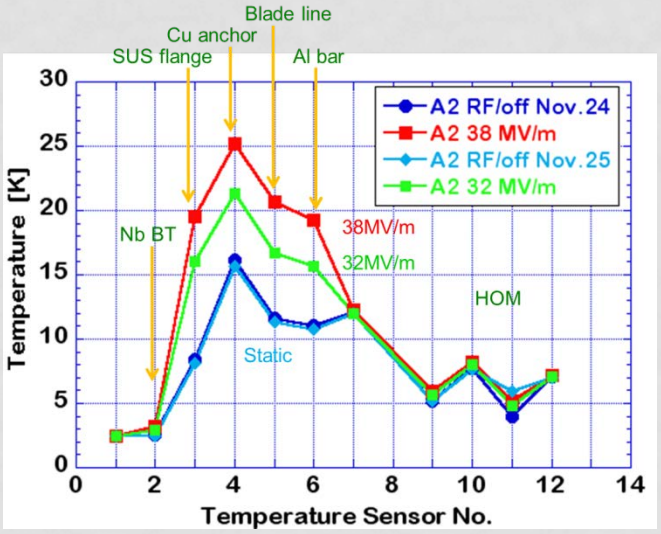
Temperature sensors at STF-2 coupler in S1-G

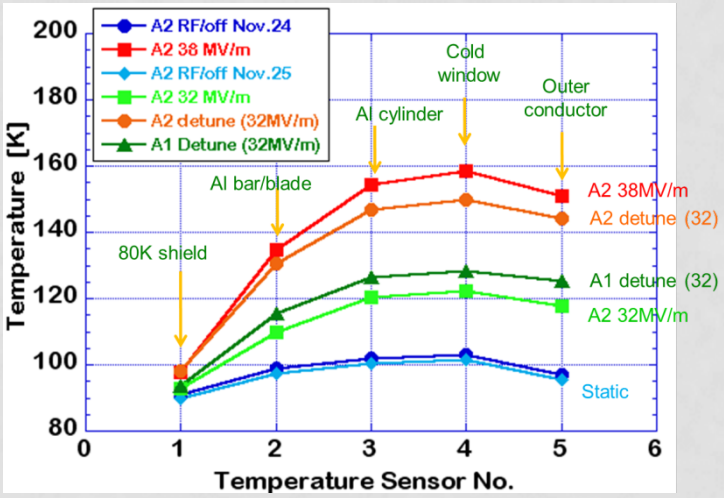
around 5K anchor (5-cernox)



around 80K anchor (5-CC)







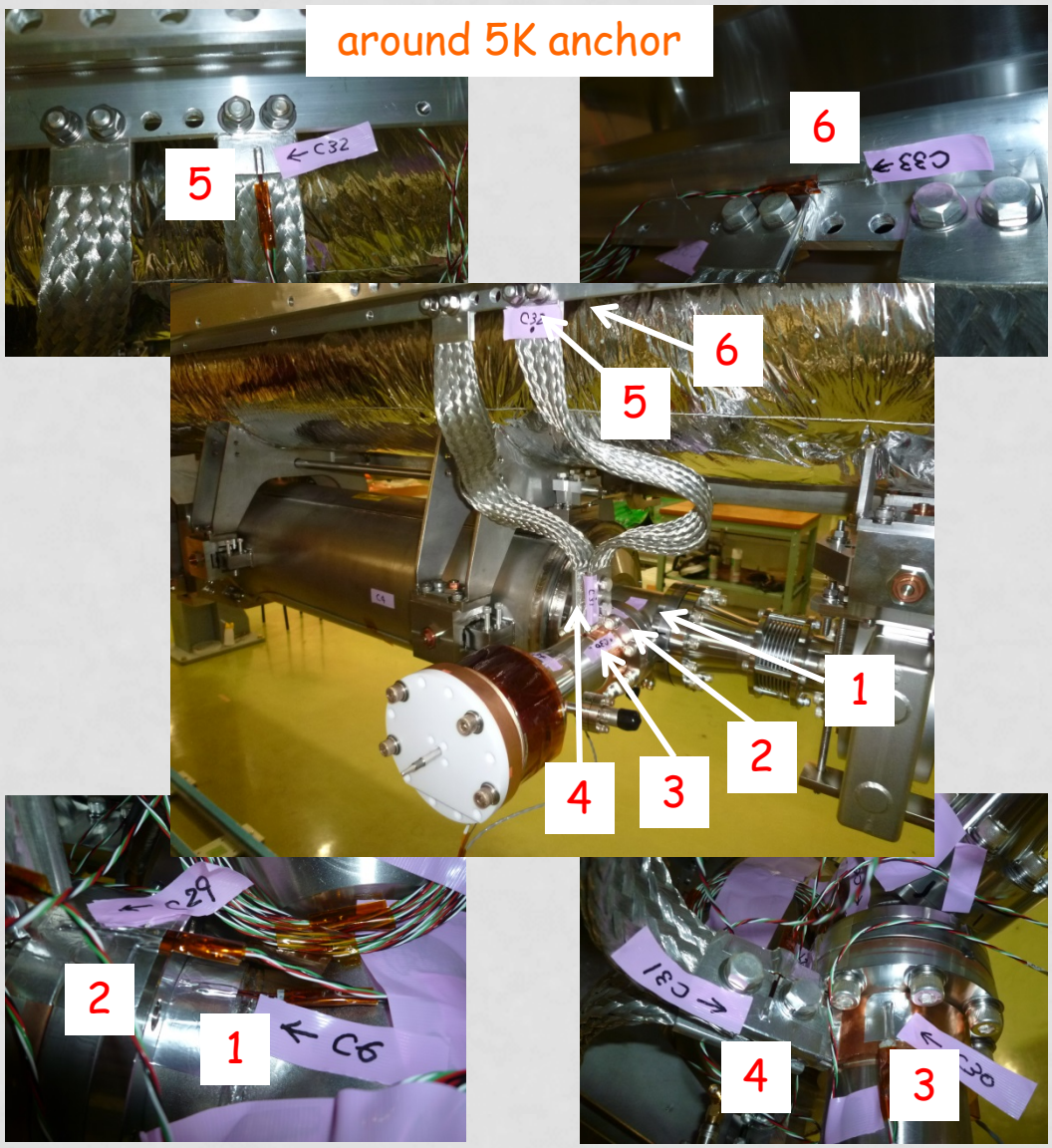
STF-2' input couplers for Capture Cryomodule

STF-2' (A) input coupler
SUS 0.8t + Cu 5 μm
Capture Cryo. - MHI-12

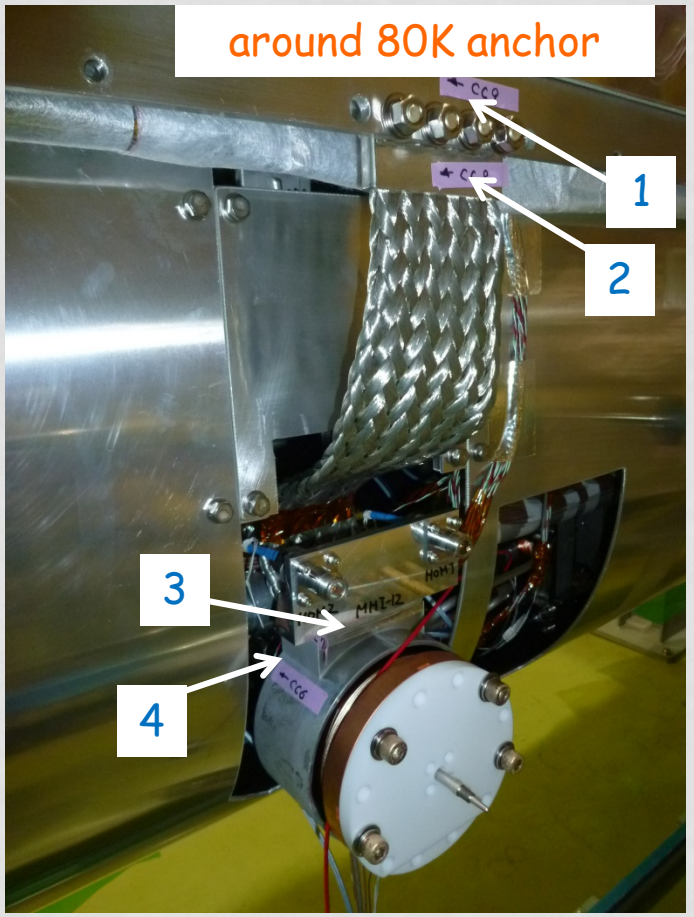
STF-2' (B) input coupler
SUS 0.8t + Cu 10 μm
Capture Cryo. - MHI-13

Temperature sensors at STF-2' input coupler

around 5K anchor



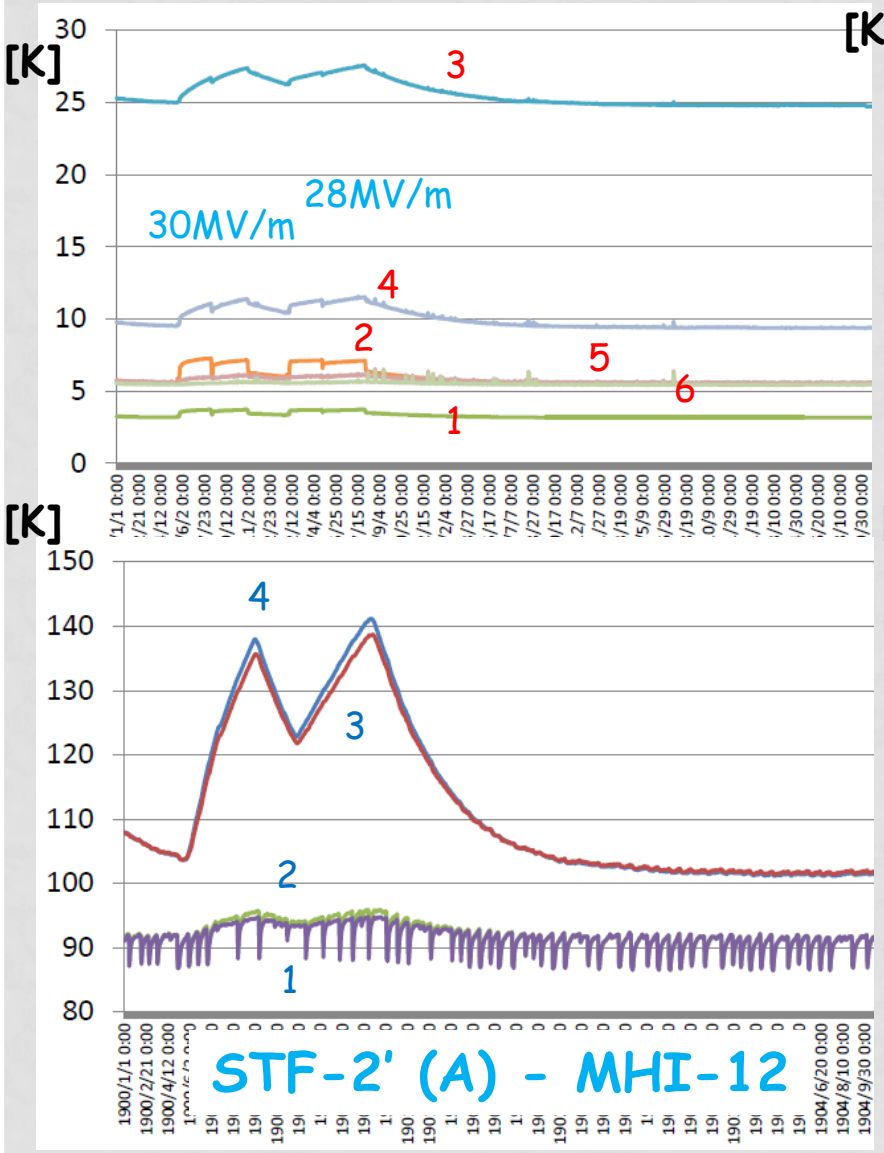
around 80K anchor

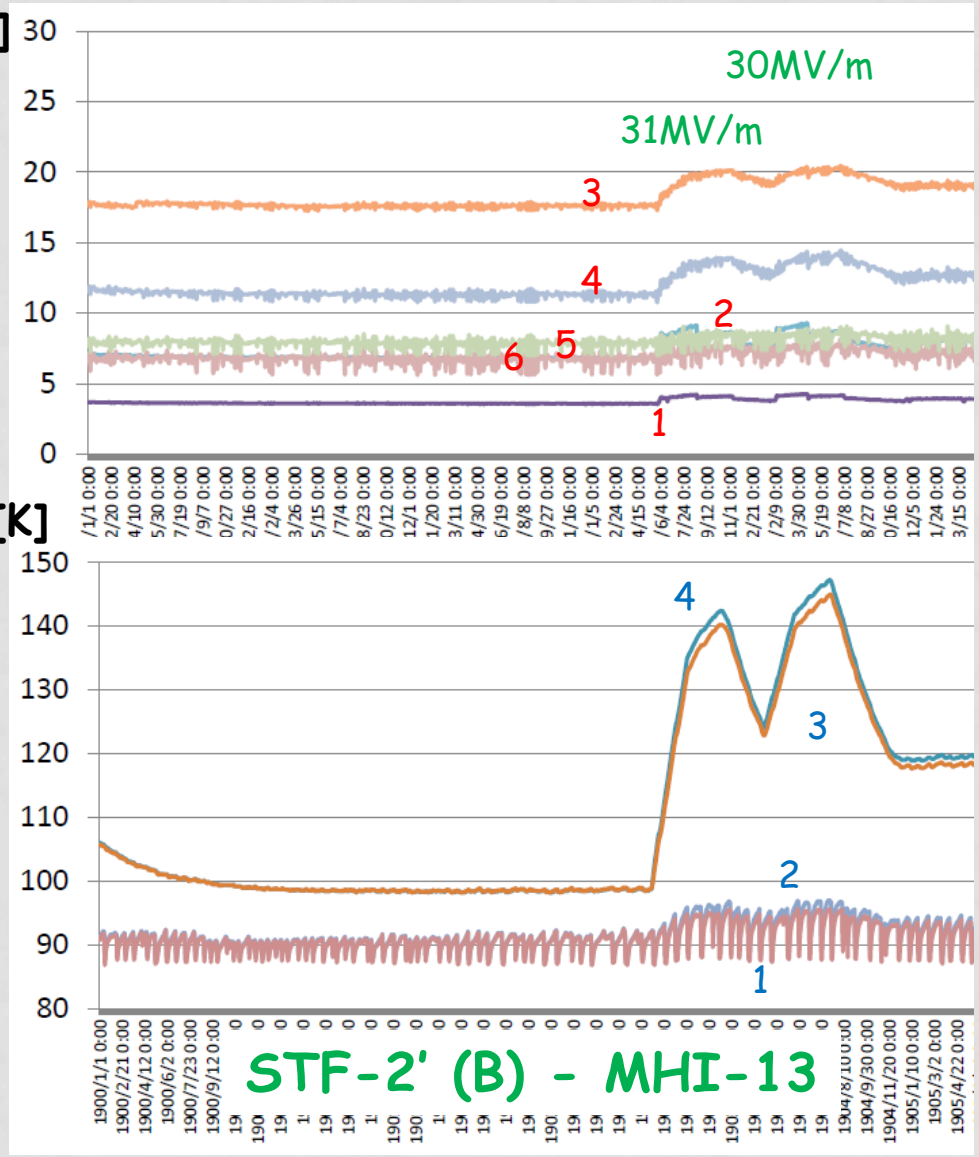


Al bus-bar was eliminated,
(not good thermal conductivity)

Cu blade-cables were used.

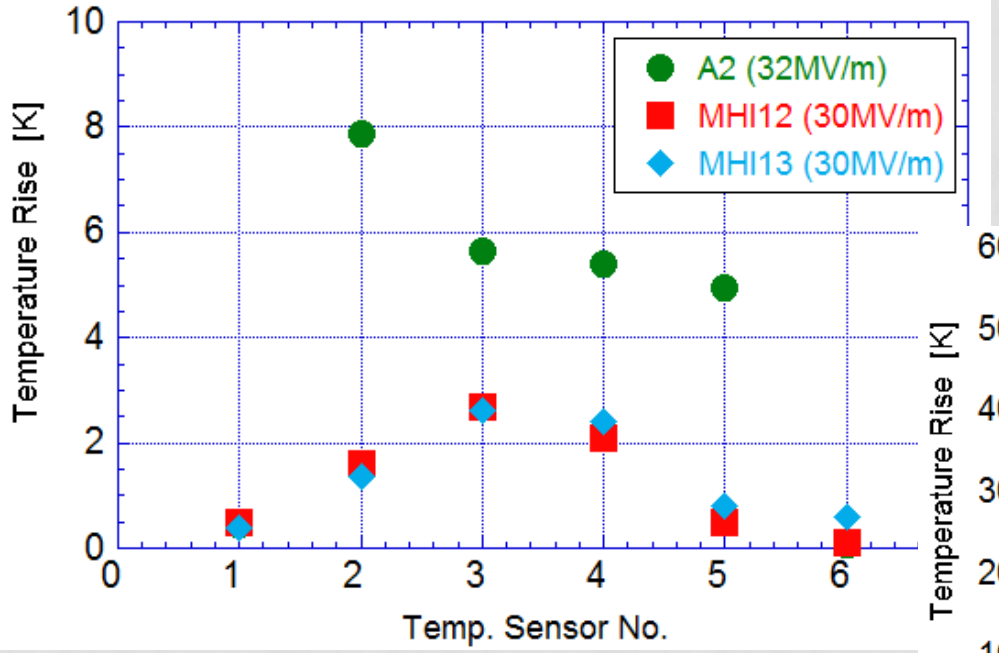
Temperature rises at input coupler (MHI-12,13)





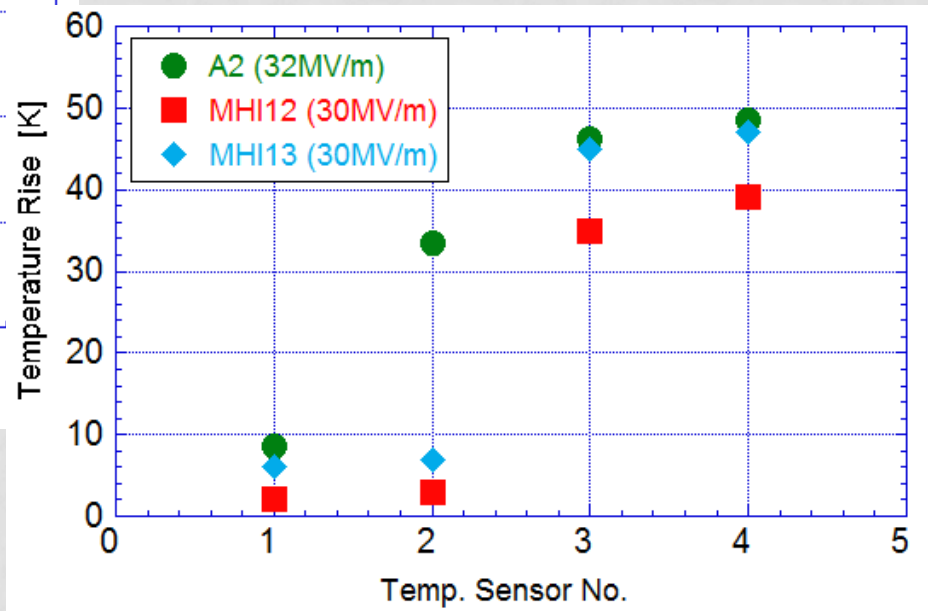
Temperature rises at input coupler (MHI-12,13)

around 5K anchor



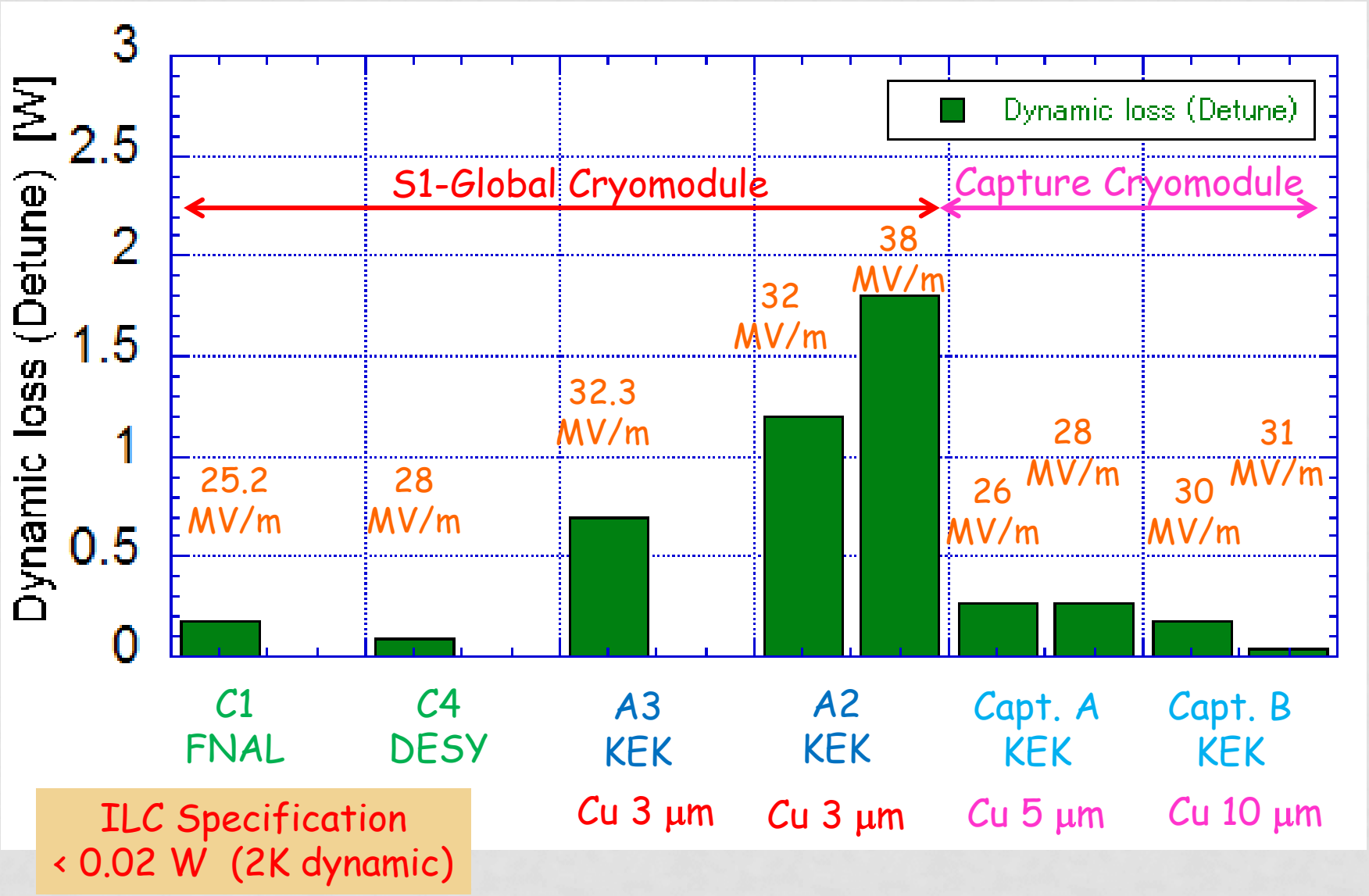
1. Nb port
2. Sus flange
3. Cu anchor
4. Blade connection-A
5. Blade connection-B
6. 5K shield

around 80K anchor



1. 80K shield
2. Blade connection-B
3. Blade connection-A
4. Cold window

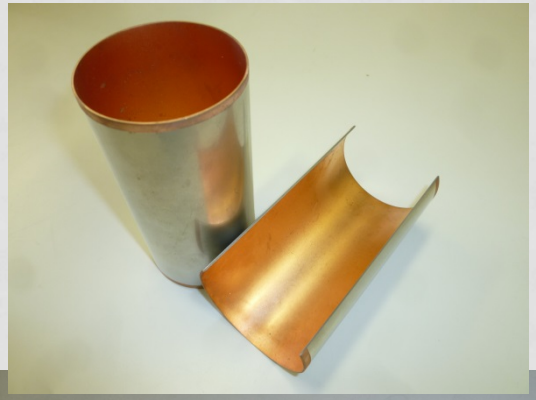
Dynamic Heat Loads at input couplers



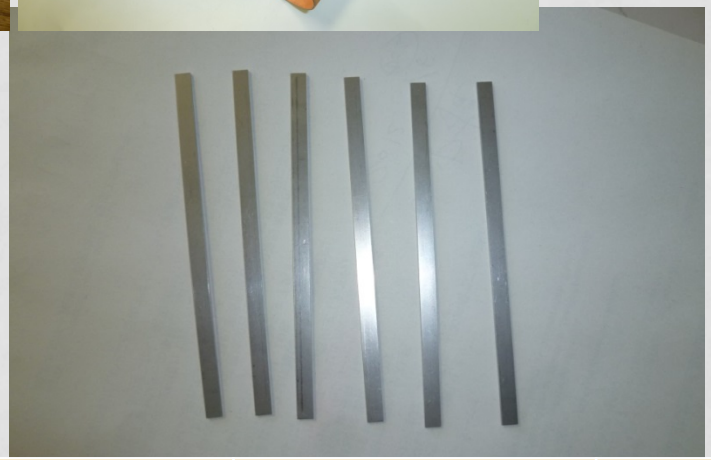
ILC Specification
< 0.02 W (2K dynamic)

RRR measurement of Cu-plating samples

Cu-plating
Samples :
SUS 1.0t
Ni-strike 0.2 μm
Cu 5 μm
(2005')

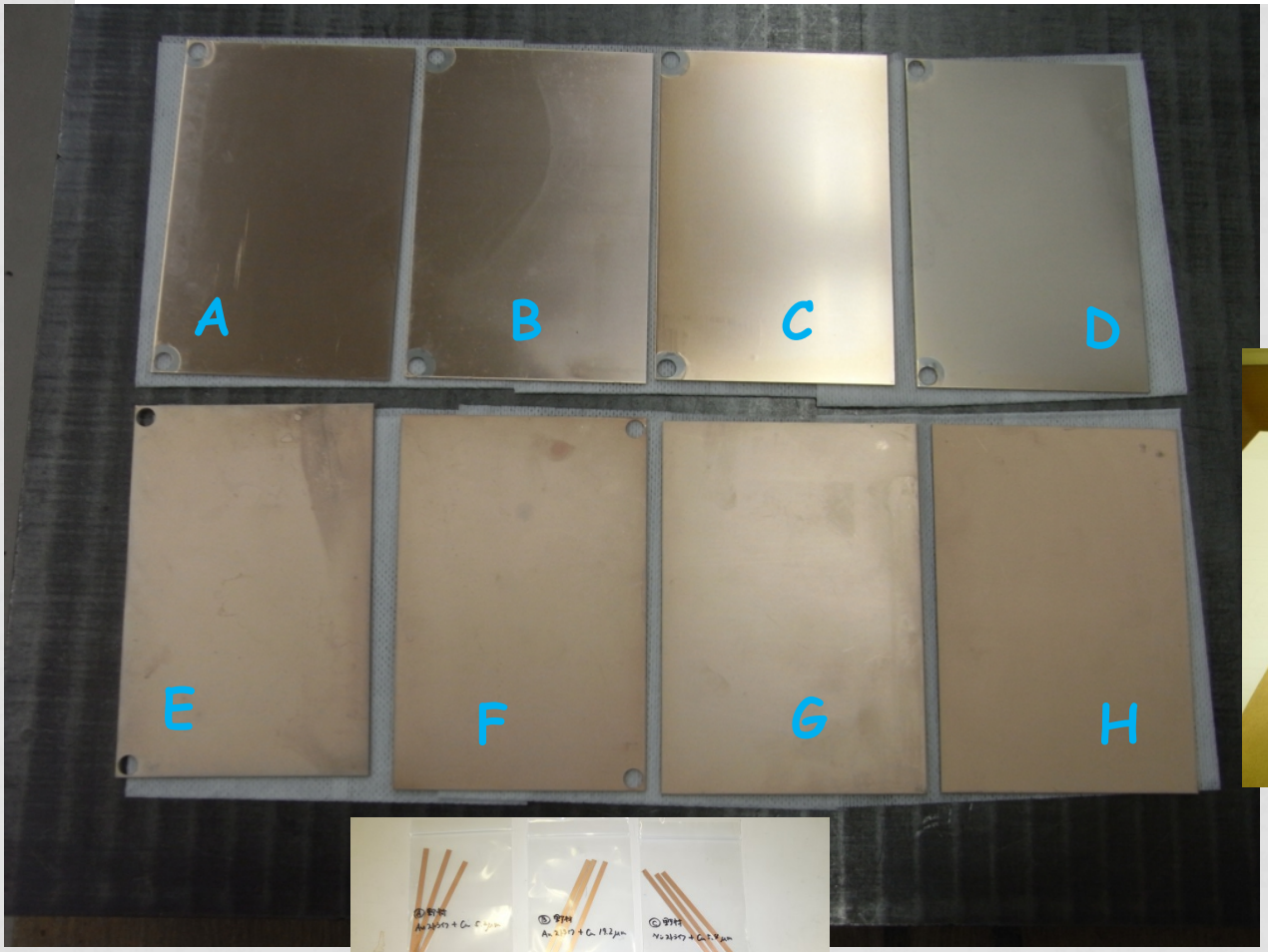


after anneal
at 800 °C
in hydrogen furnace

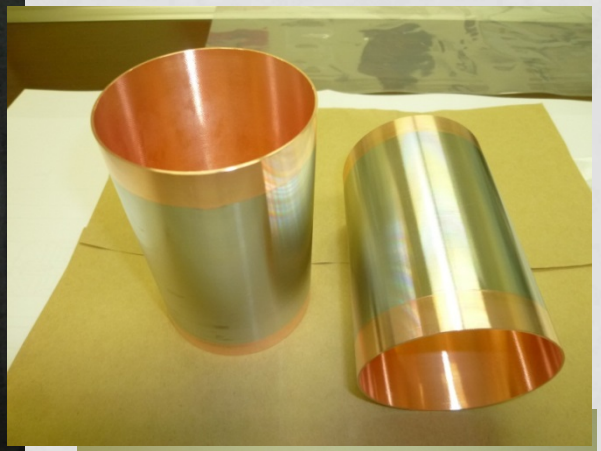


Sample	X1	X2	X3	X4
RRR (Cu+SUS)	1.43	1.44	1.44	1.42
RRR (SUS)	1.42	1.43	1.41	1.43
RRR (Cu)	1.53	1.07	2.18	1.47

RRR measurement of Cu-plating samples



0.2 μm Au-strike
+ 3 μm Cu-plating
on 0.8t SUS pipe



after anneal at 800 °C
in hydrogen furnace

RRR measurements of Cu-plating samples

Samples	(company)	Strike -plating	Cu -plating	Thickness of Cu	no anneal	after anneal
A	(N)	Ni	$Cu_2P_2O_7$	5 μm	A1, A2	A4, A5
B	(N)	Ni	$Cu_2P_2O_7$	20 μm	B1, B2	B4, B5
C	(N)	Au	$Cu_2P_2O_7$	5 μm	C1, C2	C4, C5
D	(N)	Au	$Cu_2P_2O_7$	20 μm	D1, D2	D4, D5
E	(T)	Ni	CuCN	5 μm	E1, E2	E4, E5
F	(T)	Ni	CuCN	20 μm	F1, F2	F4, F5
G	(F)	Ni	CuCN	10 μm	G1, G2	G4, G5
H	(F)	Ni	CuCN	35 μm	H1, H2	H4, H5

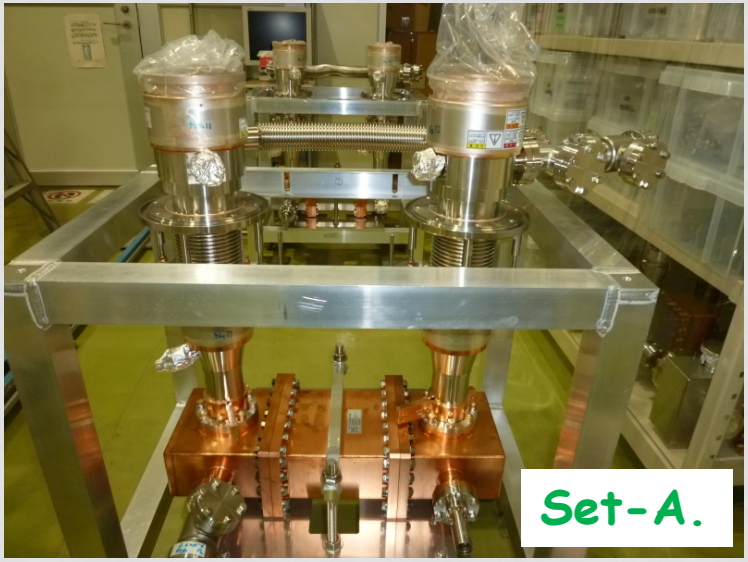
The measurements are now in progress.

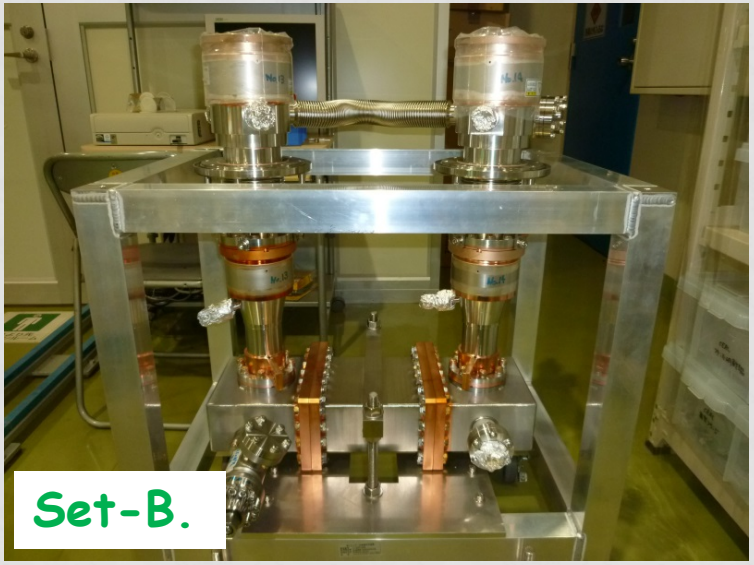
8 STF-2" input couplers for STF-2/CM1 module

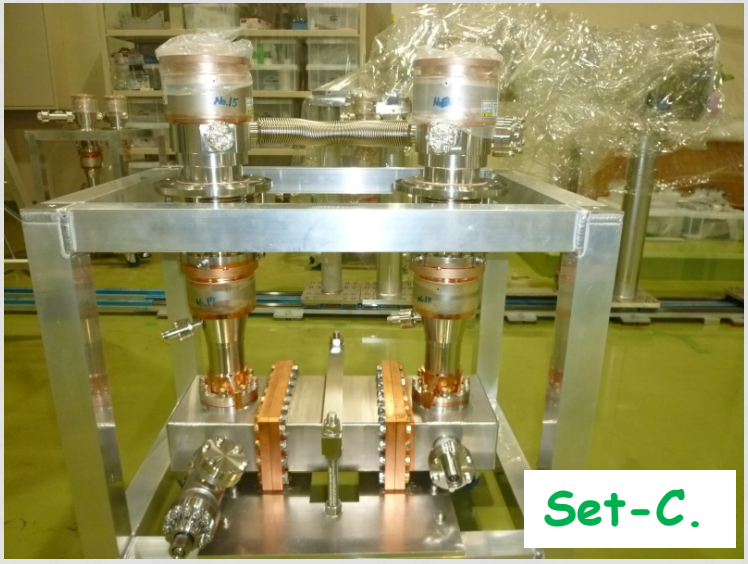
STF-2'' input couplers for STF-2/CM1 module

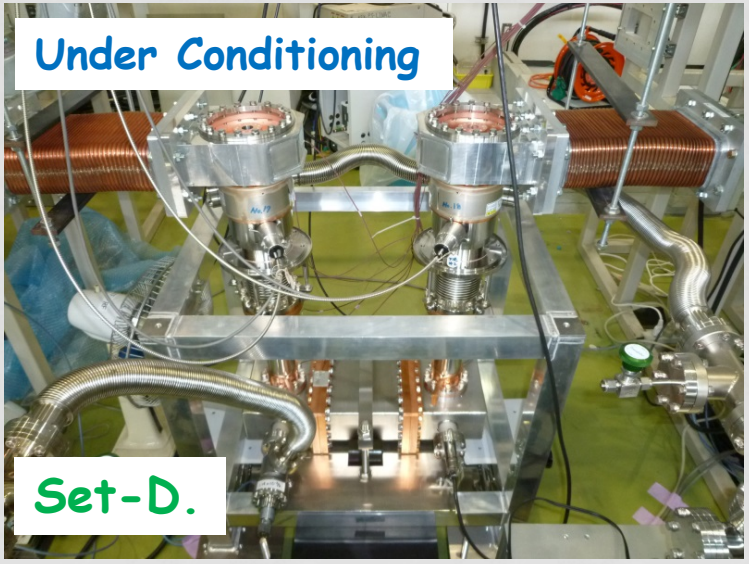
STF-2''	Cold-outer strike	Cold-outer Cu-plating	Cold -inner	Warm -outer	Warm -inner
A- No. 11	Au 0.2 μm	Cu 3 μm	Cu 20 μm	Cu 10 μm	Cu 10 μm
A- No. 12	Au 0.2 μm	Cu 3 μm	Cu 20 μm	Cu 10 μm	Cu 10 μm
B- No. 13	Au 0.2 μm	Cu 3 μm	Cu 20 μm	Cu 20 μm	Cu 20 μm
B- No. 14	Au 0.2 μm	Cu 3 μm	Cu 20 μm	Cu 20 μm	Cu 20 μm
C- No. 15	Au 0.2 μm	Cu 5 μm	Cu 20 μm	Cu 10 μm	Cu 10 μm
C- No. 16	Au 0.2 μm	Cu 5 μm	Cu 20 μm	Cu 10 μm	Cu 10 μm
D- No. 17	Au 0.2 μm	Cu 5 μm	Cu 20 μm	Cu 20 μm	Cu 20 μm
D- No. 18	Au 0.2 μm	Cu 5 μm	Cu 20 μm	Cu 20 μm	Cu 20 μm

Conditioning of 8 x STF-2" input couplers



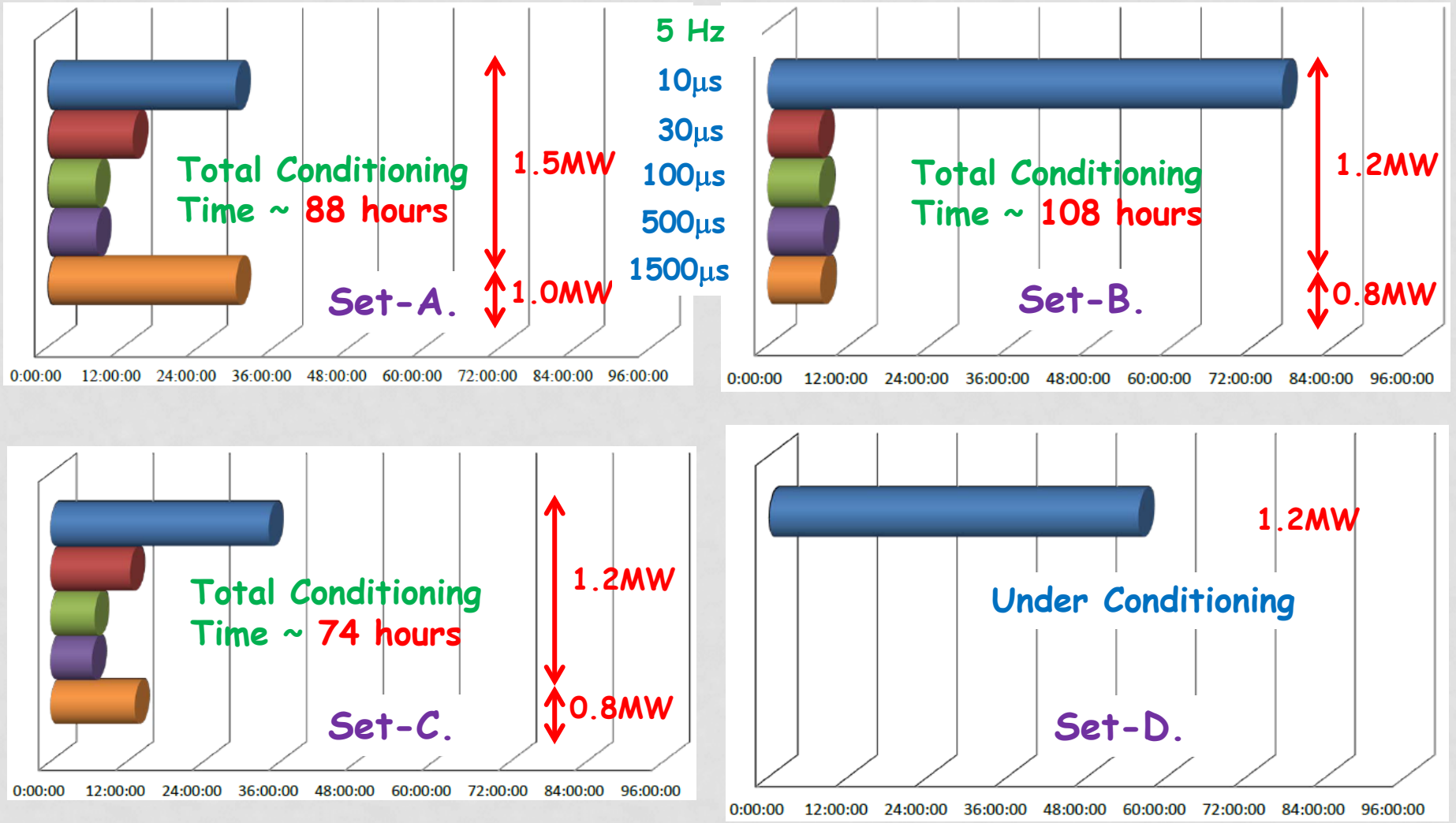




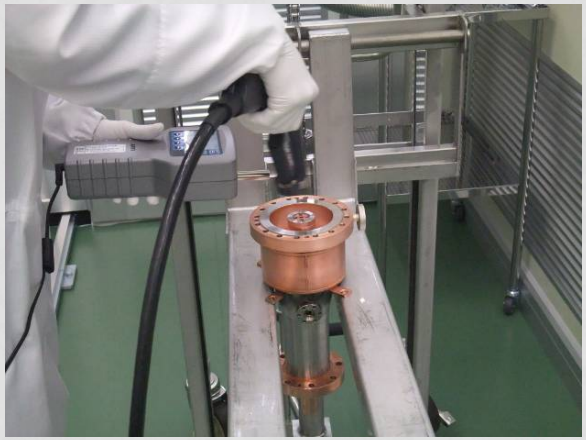


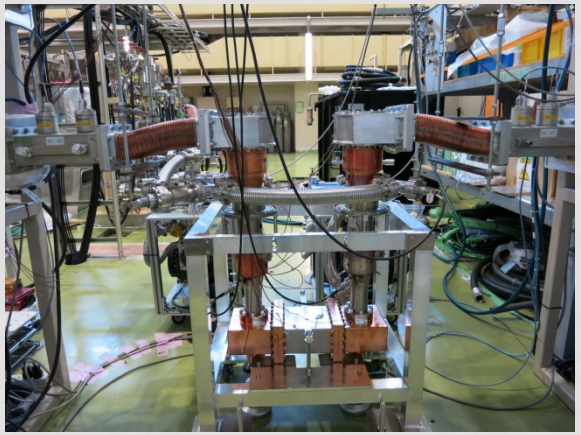
Conditioning of 8 x STF-2" input couplers

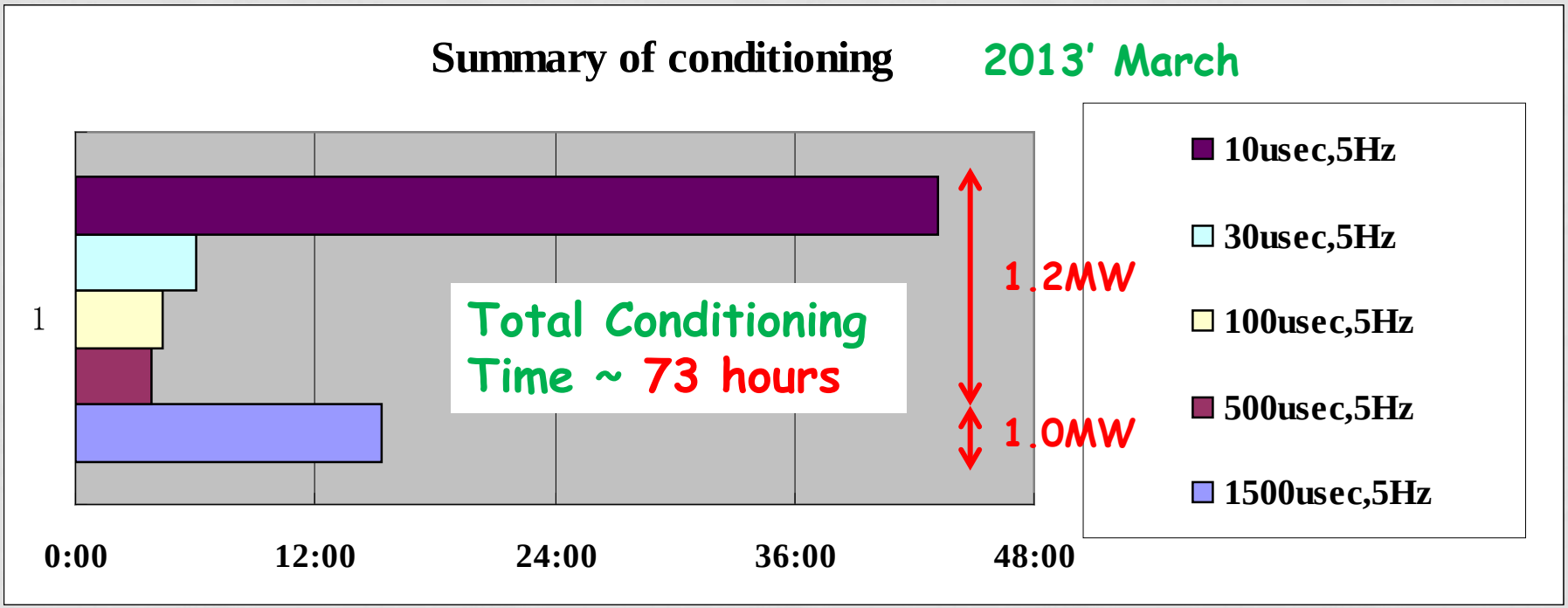
2013' Jan. ~ May



Conditioning of IHEP couplers at KEK-STF



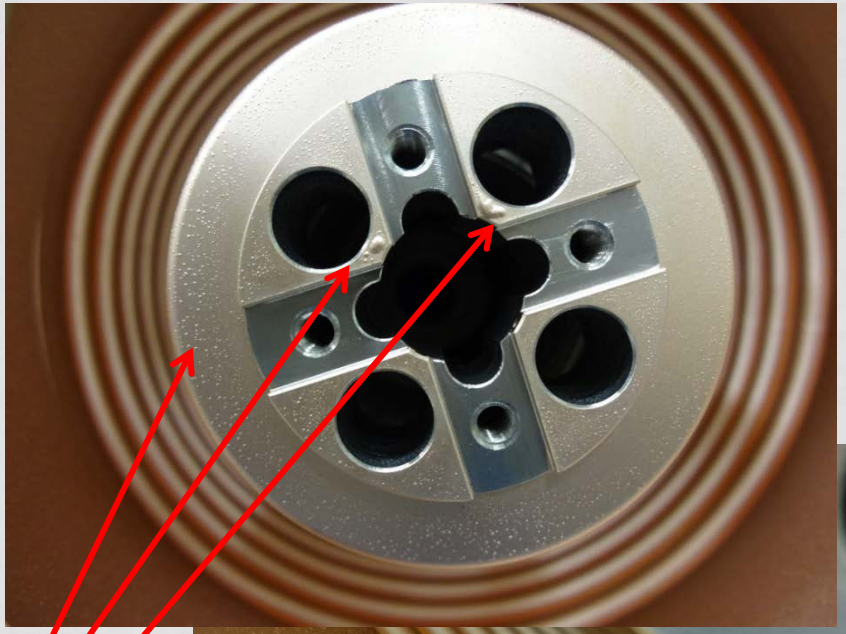


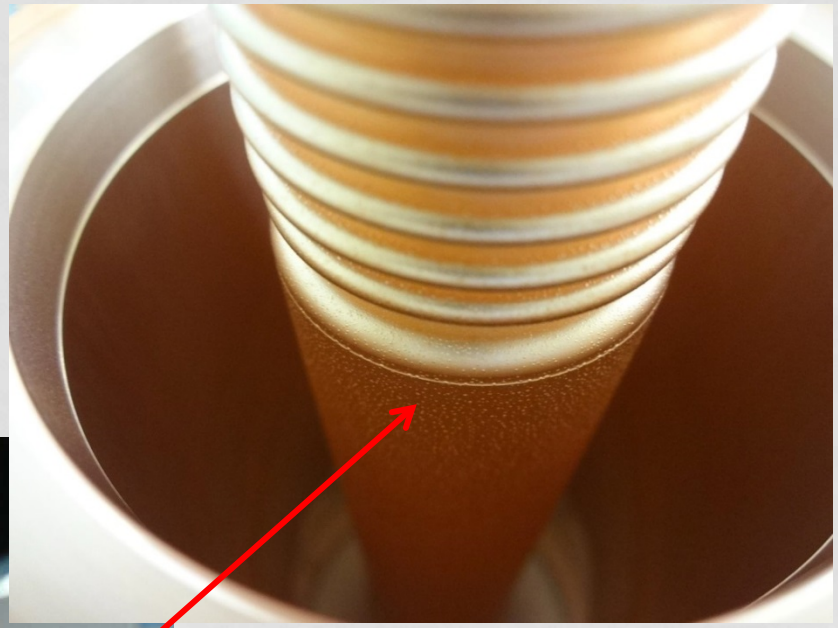


4 STF-2" input couplers for STF-2/CM2a module

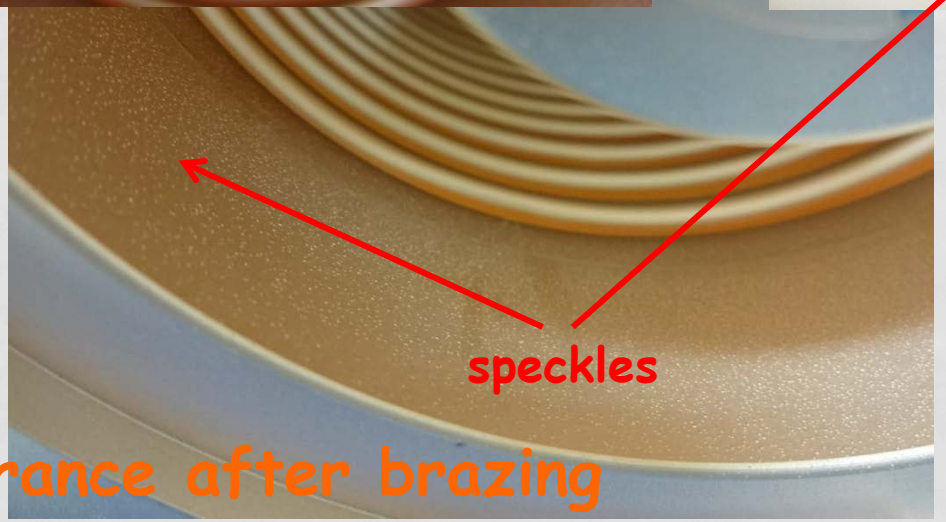
2013' March

Problem of Cu-plating in STF-2" input couplers

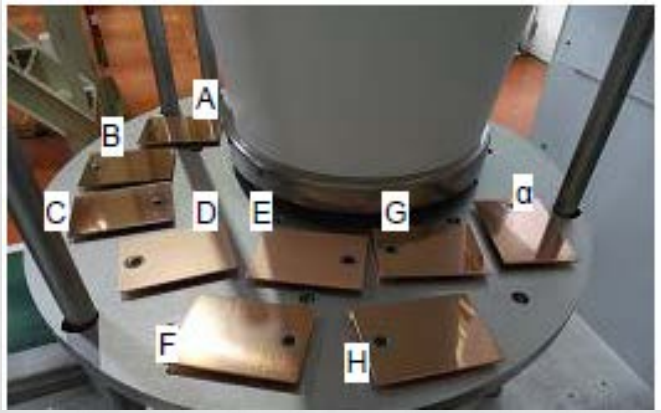




blisters



appearance after brazing



Cu-plating samples

Summary

- STF input couplers at KEK have been improving step by step.
- Quality control of thin Cu-plating is essentially important technology.

END

Thank you for your attentions.