High field experiment with narrow waveguide

Kazue Yokoyama, Toshiyasu Higo, Yasuo Higashi, Noboru Kudo, Shuji Matsumoto

Accelerator Laboratory, KEK

Introduction

- We have been studying on the characteristics of different materials on high-gradient RF breakdown at Nextef (New X-band Test Facility at KEK).
- We have performed experiments by using a reduced cross-sectional waveguide that has a field of approximately 200MV/m at an RF power of 100MW.
- Today's presentation is about a status report of the high-gradient testing of copper(Cu002) and stainless-steel waveguides(SUS003).

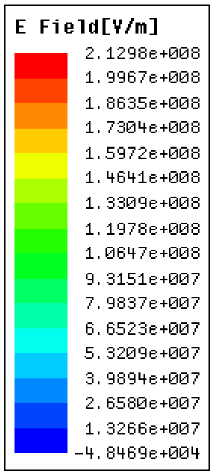
Contents

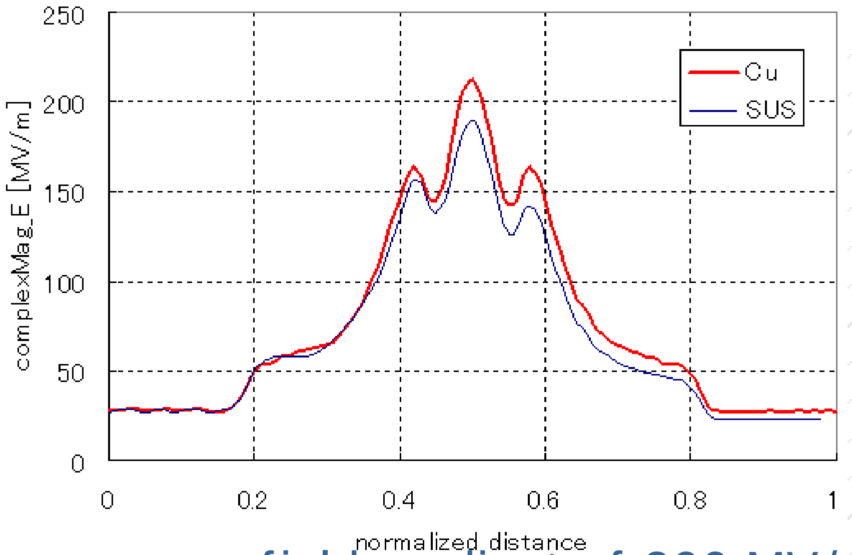
1. Design and Fabrication of Narrow Waveguide
2. Experimental Setup
   - CU002 at XTF (old X-band Test Facility at KEK)
   - SUS003 at Nextef (New X-band Test Facility at KEK)
   - Scheme of RF Processing
3. Results of High-Power Testing
4. Summary

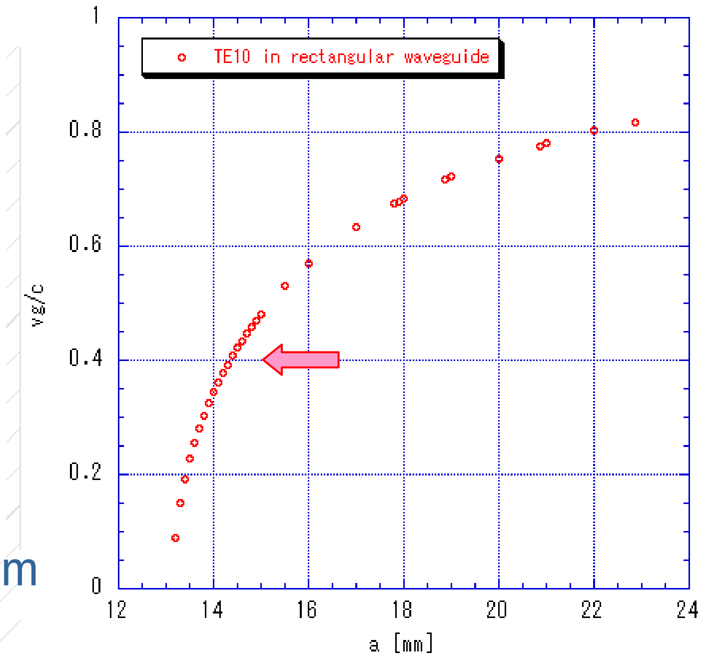
1. Narrow Waveguide

- Design
- Fabrication

Narrow Waveguide Design

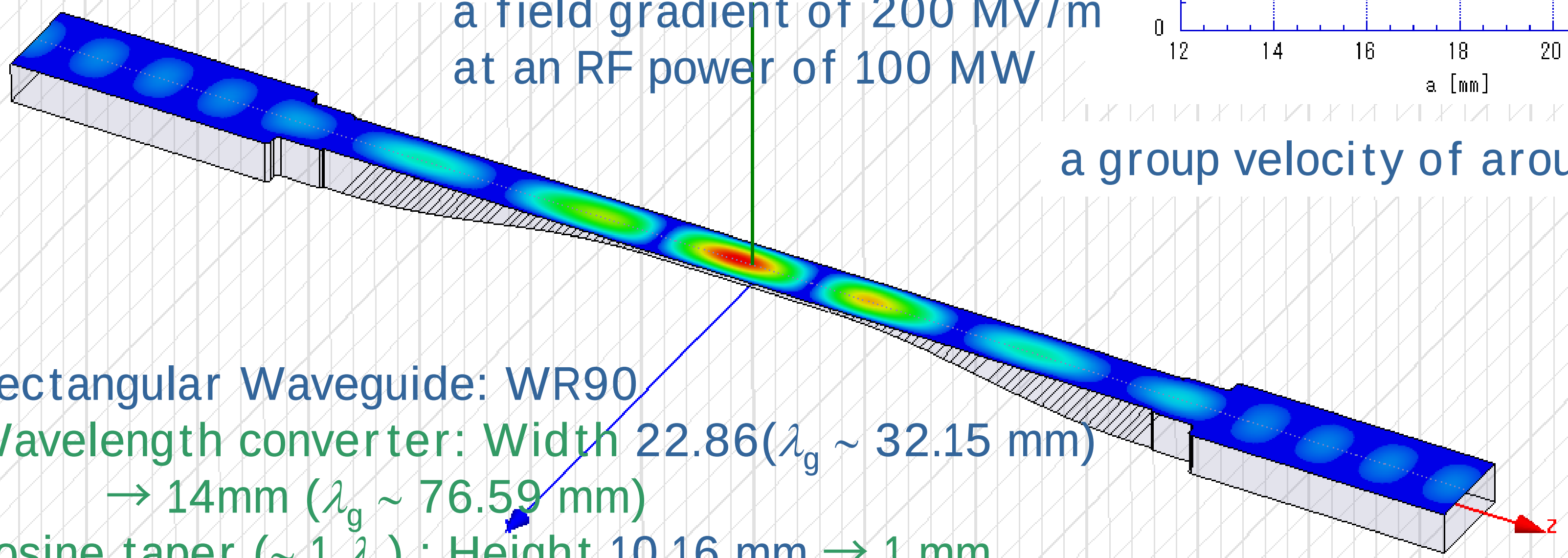






a field gradient of 200 MV/m
at an RF power of 100 MW

a group velocity of around 0.3c



Rectangular Waveguide: WR90

Wavelength converter: Width 22.86(λ_g ~ 32.15 mm)

→ 14mm (λ_g ~ 76.59 mm)

Cosine taper (~ 1 λ_g) : Height 10.16 mm → 1 mm

Fabrication

➢Narrow waveguide consists of 4 pieces.
➢They were bonded by brazing in a hydrogen furnace at the KEK mechanical engineering centre.

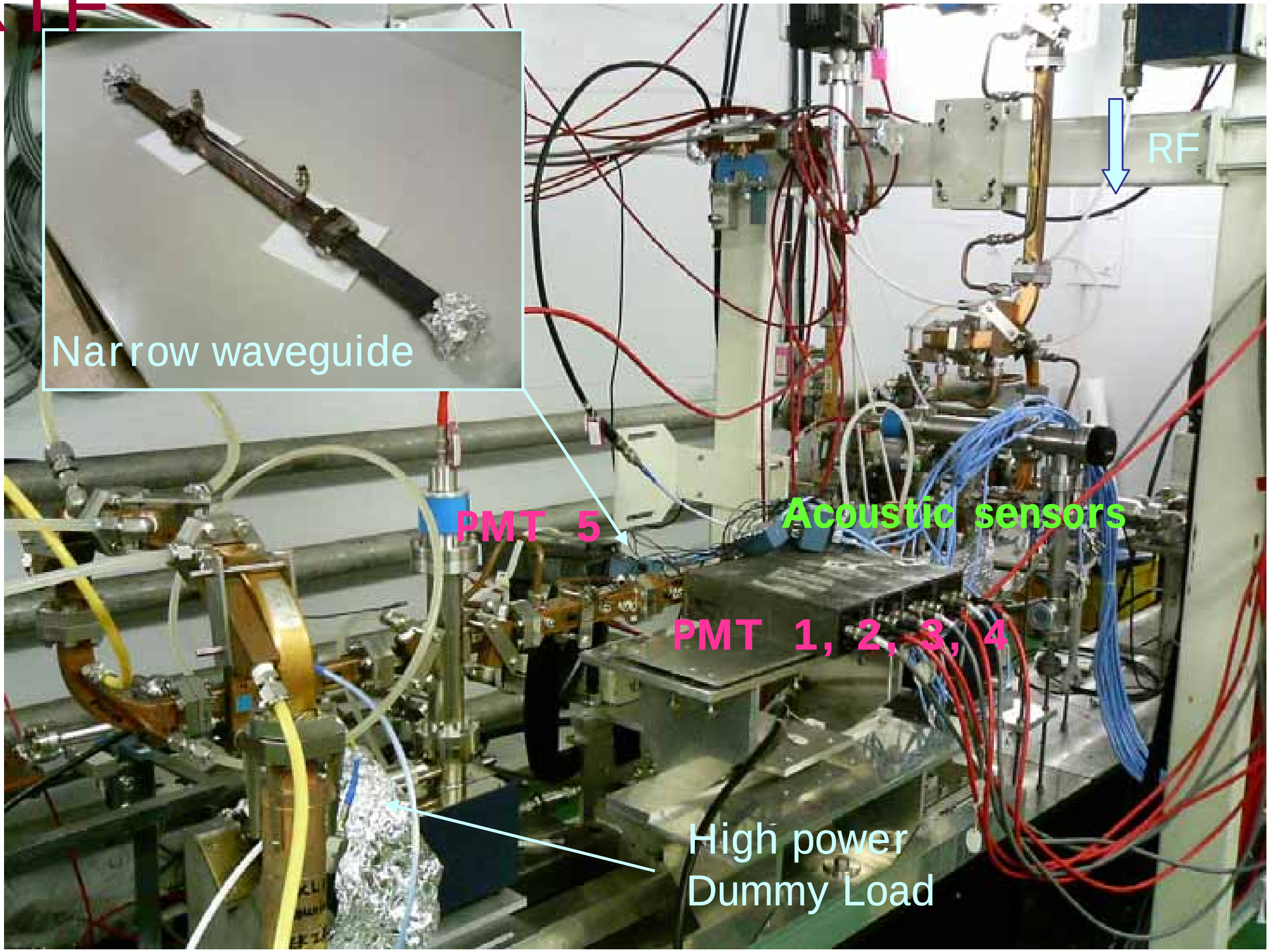
	Cu-002	SUS-003	Cu-004
material	OFC	SUS316L	OFC
anneal	500 °C	1020 °C	500 °C
processing	milling, WEDM	milling	milling
cleaning	CP	SUSpika	CP
bonding	Cu/Au/Ni, hydrogen furnace	Cu/Au, hydrogen furnace	Cu/Au hydrogen furnace
VSWR @11.424 GHz	1.4	1.12	1.02
status	Tested at XTF	Tested at Nextef	plan to be tested on Feb.

➢Annealing in a hydrogen furnace
➢Processing by milling and and wire electrical discharge machining (WEDM)
➢For the E-plane where the electric field is applied, the surface was finished by milling.
➢The pieces were chemically polished 10 μm in an acid solution.

2. Experimental Setup

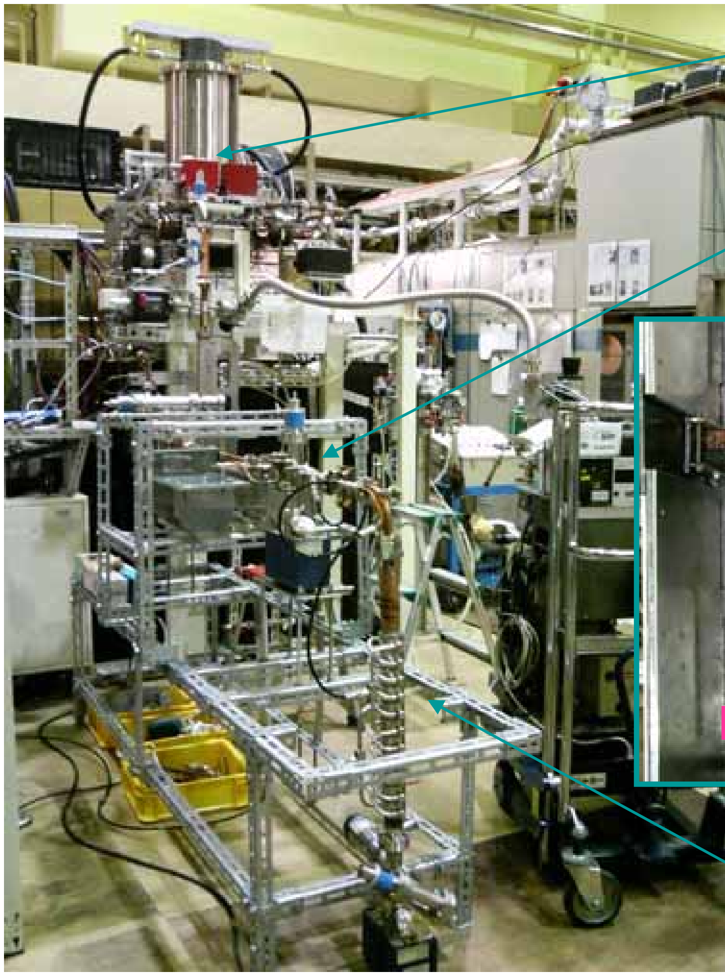
- CU002 at XTF
- SUS003 at Nextef
- Scheme of RF Processing

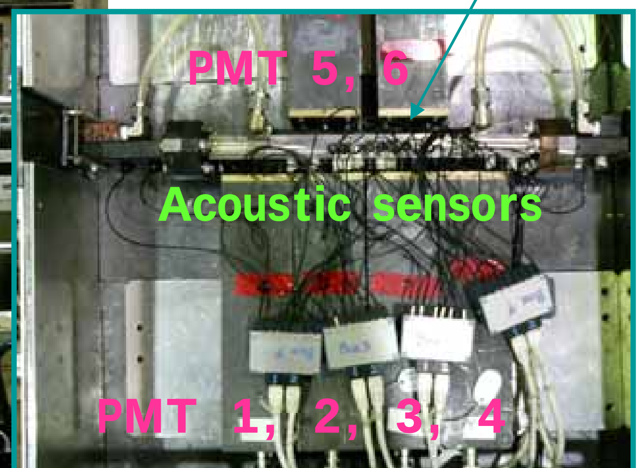
Cu002 Setup for High-Power processing @XTF



➢The first high-power test of copper(Cu002) was done at XTF (previous X-band Test Facility at KEK).

SUS003 Setup for High-Power processing @ Nextef

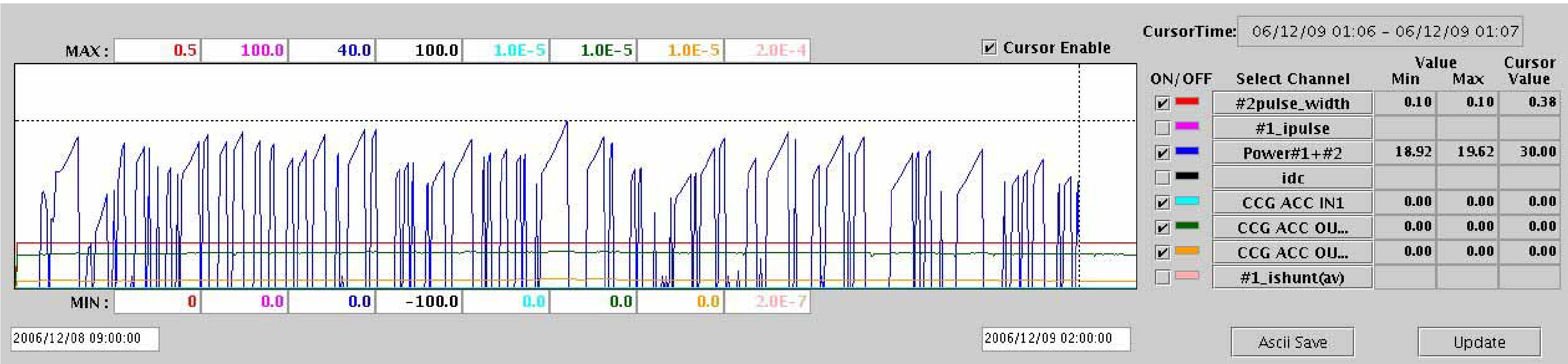




- Cu002
  - tested at XTF (06.11～07.01)
  - Moving to Nextef (～ 07.04)
  - Using for system checking (～ 07.05)
- SUS002
  - Tested at Nextef (～ 08.01)

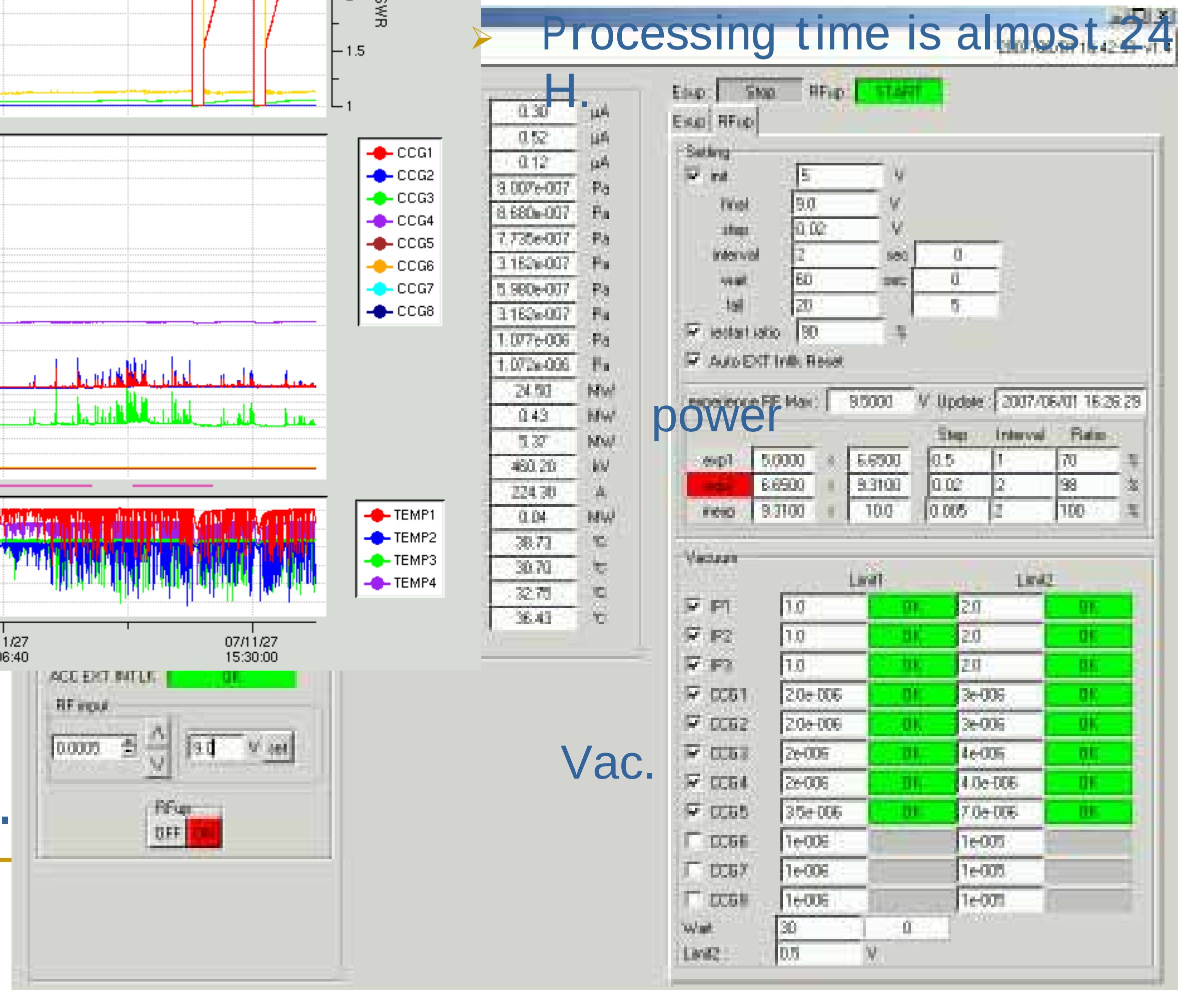
- We are on going high power testing of stainless-steel(SUS003) at Klystron Test Stand.

Processing Scheme @XTF



- Basically, working an interlock system when a reflect power is larger (vswr>1.4) and vacuum becomes worse to protect RF components.
- Options:
- We control fixed time step and power step.
- We had many rf break down in a short time after breakdown cause worse vacuum condition.
- We are able to do processing during only day time (9:00 -20:00).

Processing Scheme @Nextef



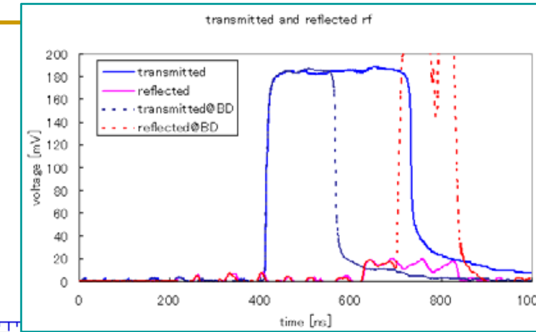
- Controlling time step (flexible)
- Controlling power step by limiting Vac. (flexible)
- Processing time is almost 24 H.

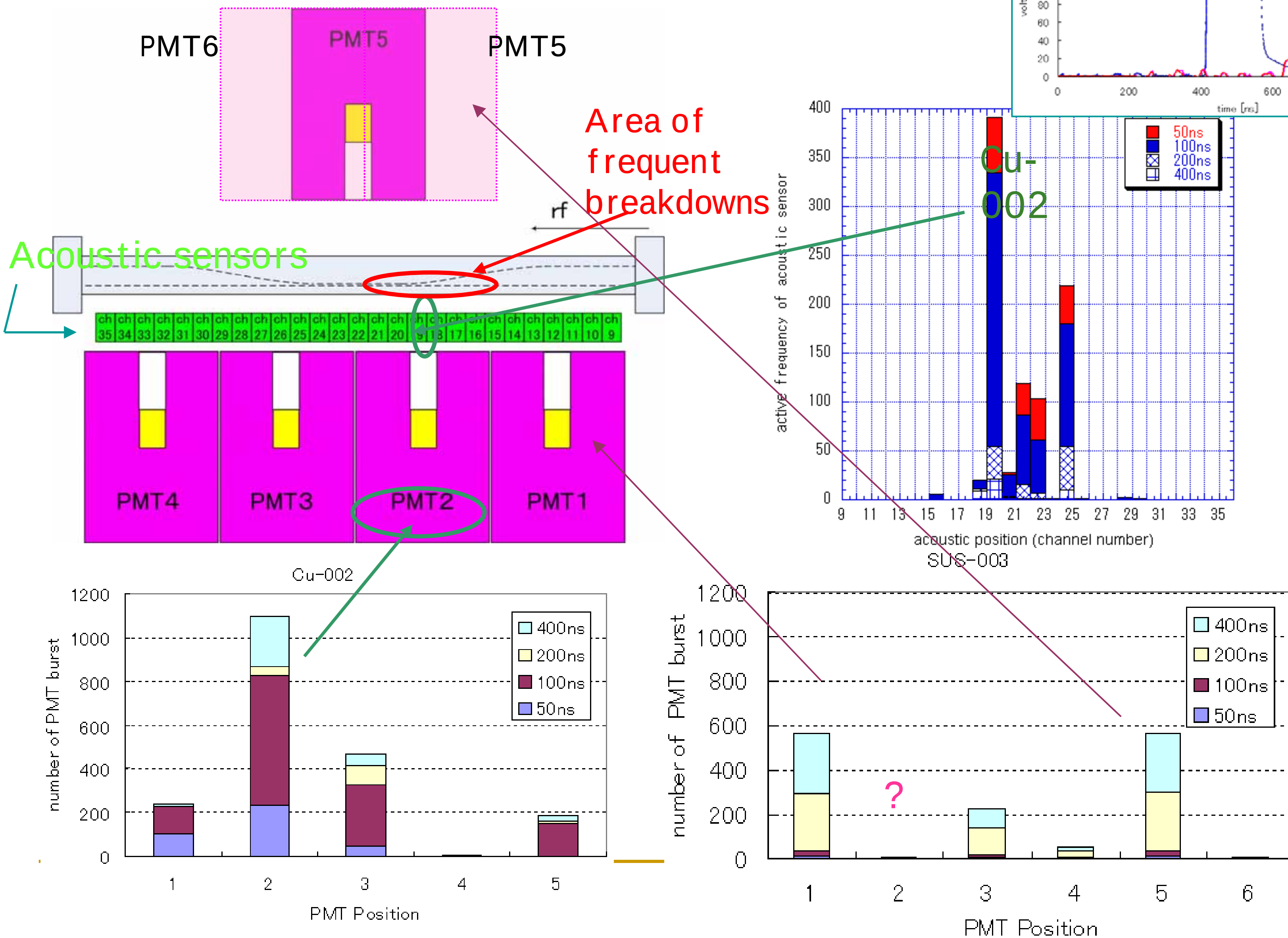
- We're seeking for ways of processing.

3. Results of High-Power Testing

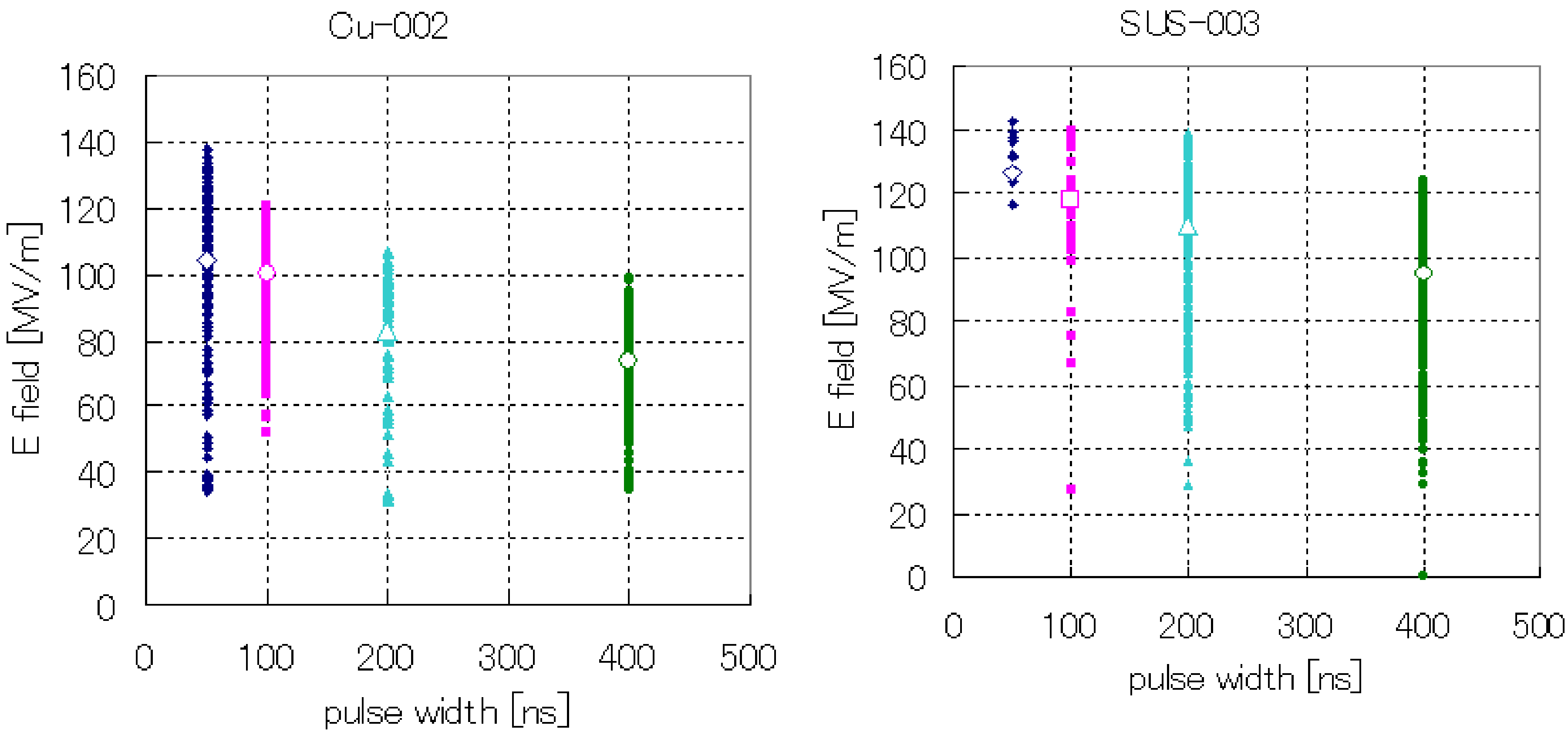
- Breakdown location
- RF Pulse width vs. Max. Electric Field
- RF Power vs. number of BD events
- Accumulated number of breakdown events vs. P*T^0.5 during processing
- Observation of Cu002 surface

Breakdown location





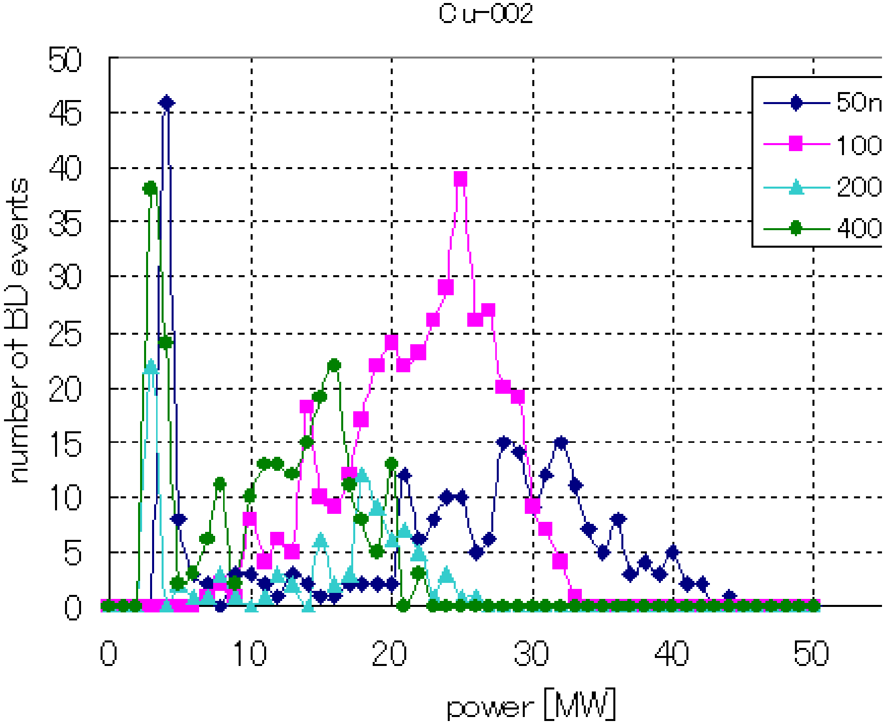
RF Pulse width vs. Max. Electric Field

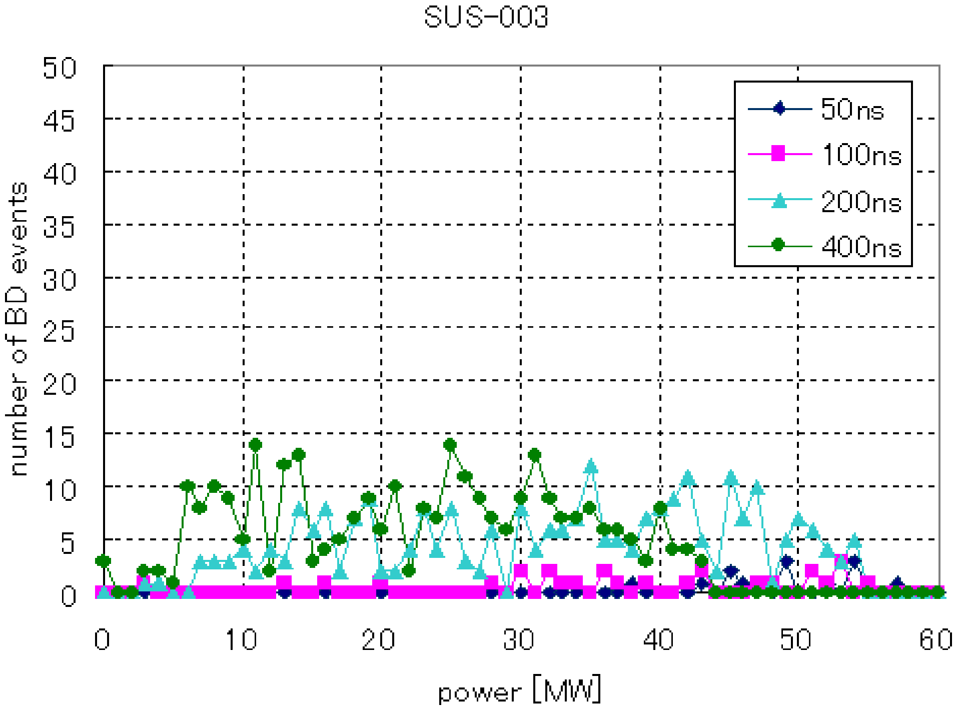


- SUS003 attained higher electric field than Cu002 with few break down events.

RF Power vs. number of BD events

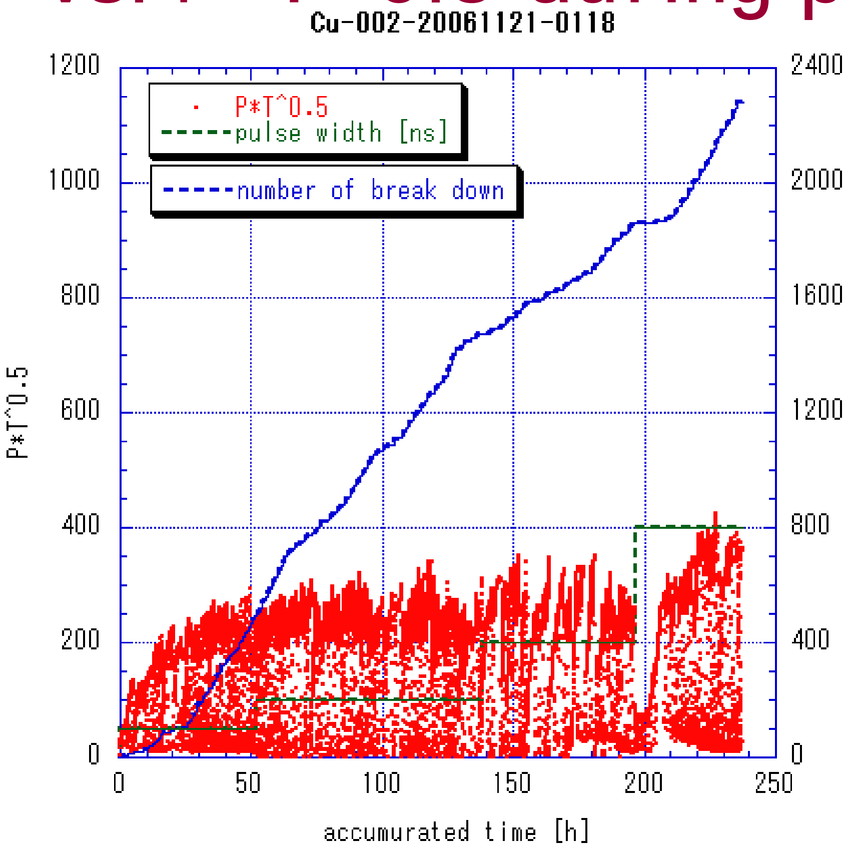
- The RF pulse went from 50 ns to 400 ns feeding up to 50 MW of power at a repetition rate of 50 pps.

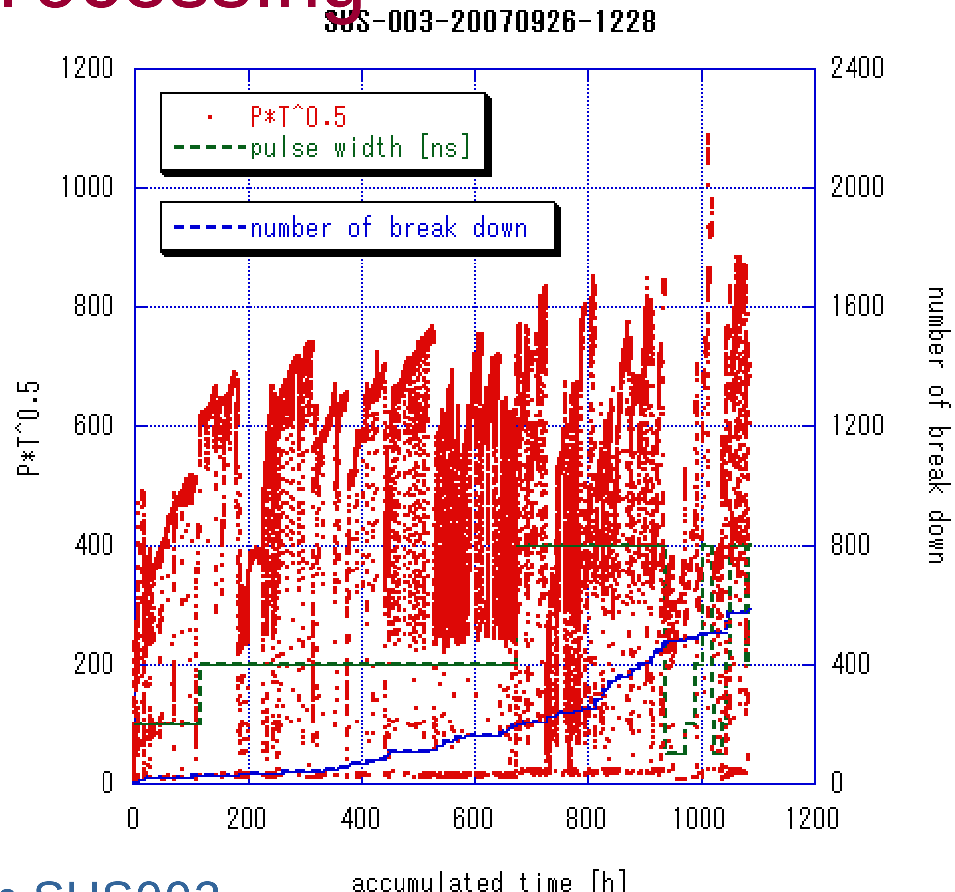




- Many breakdown events at pulse width of more than 100 ns and at the power of 20 MW.
- Few RF break down events at 50 ns and 100ns .
- We had a guard window problem around 200ns.

Accumulated number of breakdown events vs. P*T^0.5 during processing

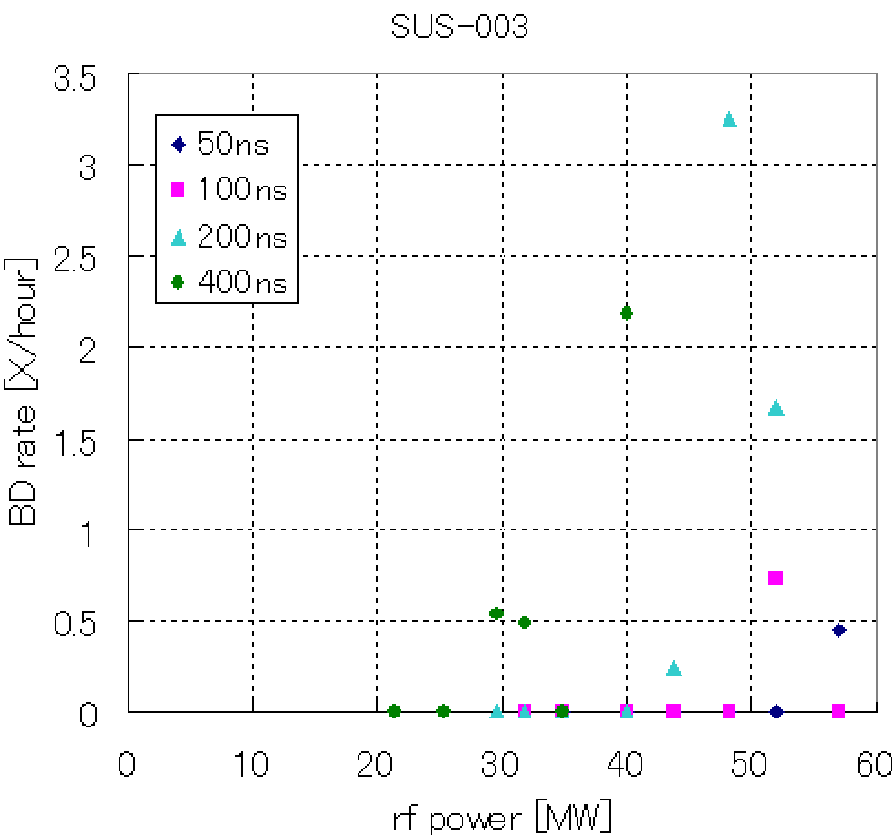




- Cu002 had much BD events than SUS003.
- The temperature related parameter, P*T1/2, attained approximately 400 MW·ns1/2 of Cu002 and 1000 MW·ns1/2 of SUS003.

P*T^0.5 – the product of RF power and the square root of the pulse width

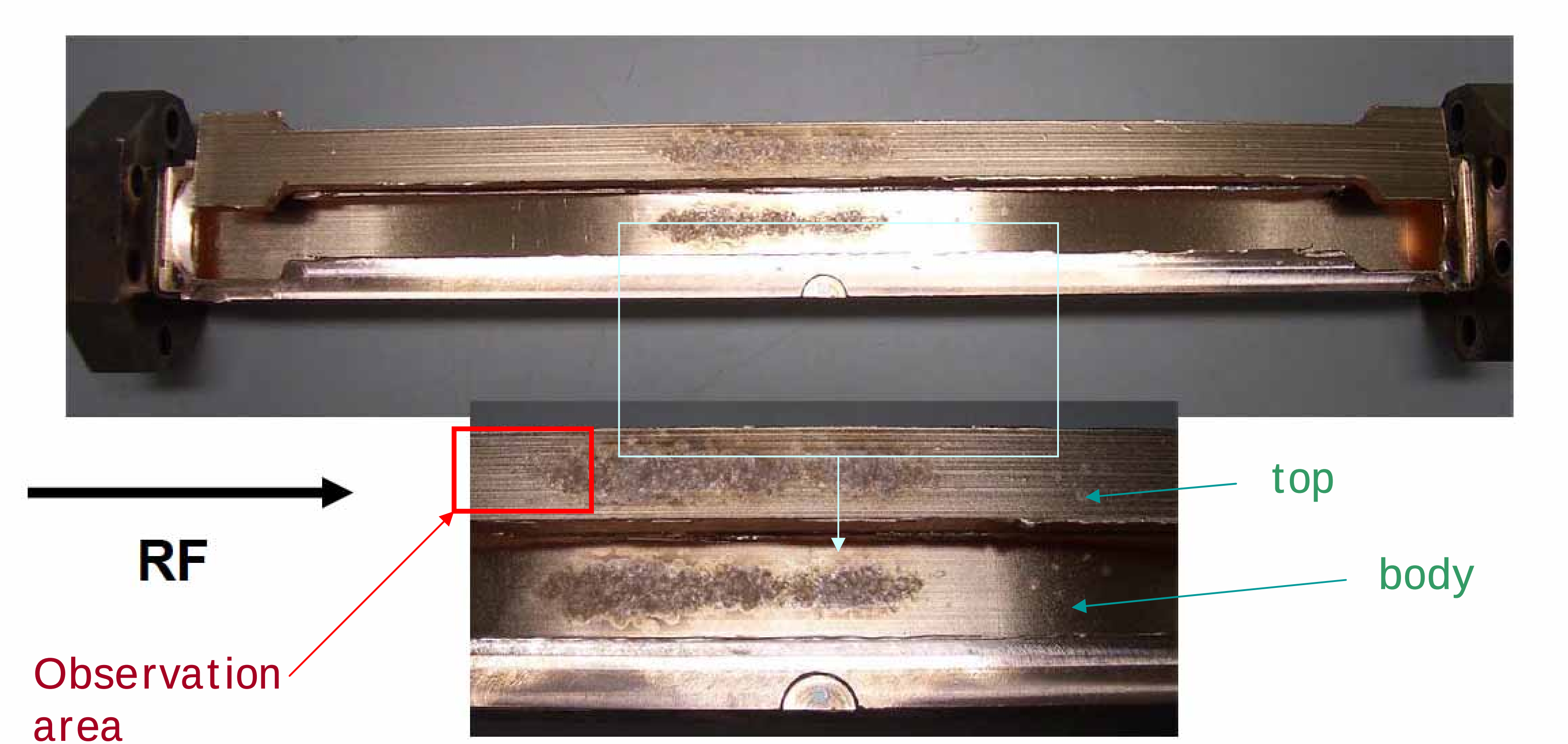
Breakdown Rate of SUS003



Input U/D	RF output power [MW]	50 [ns]	100 [ns]	200 [ns]	400 [ns]
5.7	21.39				0
6	25.25				0
6.3	29.66			0	2
6.6	31.85		0	0	2
6.8	34.80	0	0	0	0
7.1	40.06	0	0	0	2
7.3	43.72	0	0	1	
7.6	48.30	0	0	14	
7.95	52.08	0	3	9	
8.5	56.97	2	0		
total		2	3	24	6

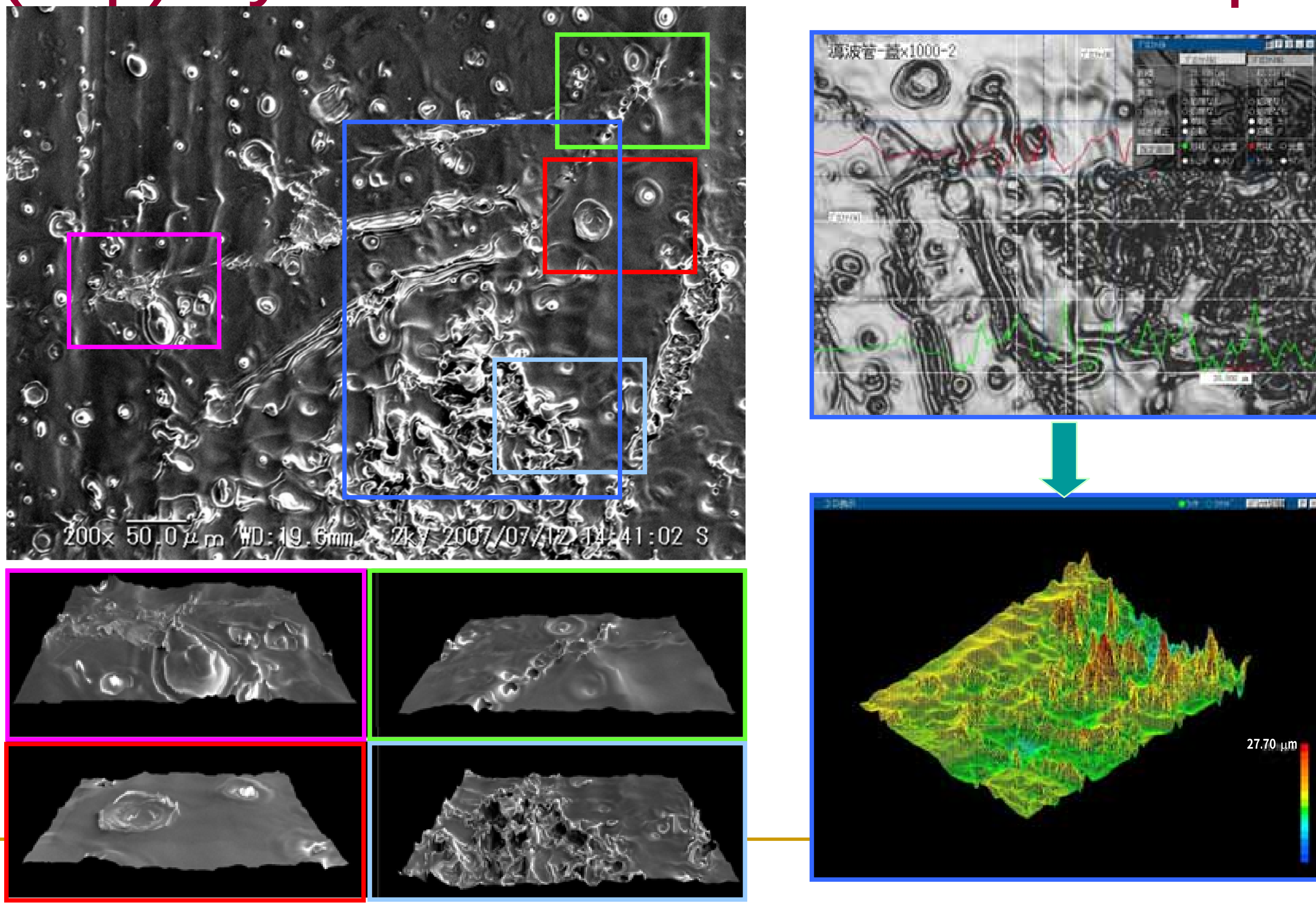
- We are trying to measure the BD rate after processing.
- We put on the constant power every four hours at 50 Hz.

Cu002 After high-power processing



- Many breakdown damages were seen on the E-plane surface.
- The surface is intensively damaged, and it could also melt due to breakdown.

Observation of Breakdown surface (top) by SEM and Laser Microscope



Summary

- RF breakdown studies on different material has just started.
- Prototype Cu002 and SUS003 had been tested under different system condition.
- Number of break down events of SUS003 are less than that of Cu002. But there's possibility of being caused by different system.
- We're seeking a processing scheme and an estimating BD rate.
- We're preparing to observe the surface of SUS003 after high-power processing.
- We're going to test Cu004, other stainless-steel waveguide and to plan to test different material in the future.