KEK Testing Programs toward X-band CLIC

X-band structure design and testing program workshop
CERN, June 18-19, 2007

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1. KEK main staffs for X-band activity
2. Klystron test stand
3. High field test with narrow waveguide
4. High-Gradient Test Facility (New XTF)
5. Fabrication facility
6. Future plans and possible collaborations.

KEK staffs working on X-Band
about 5 FTE now

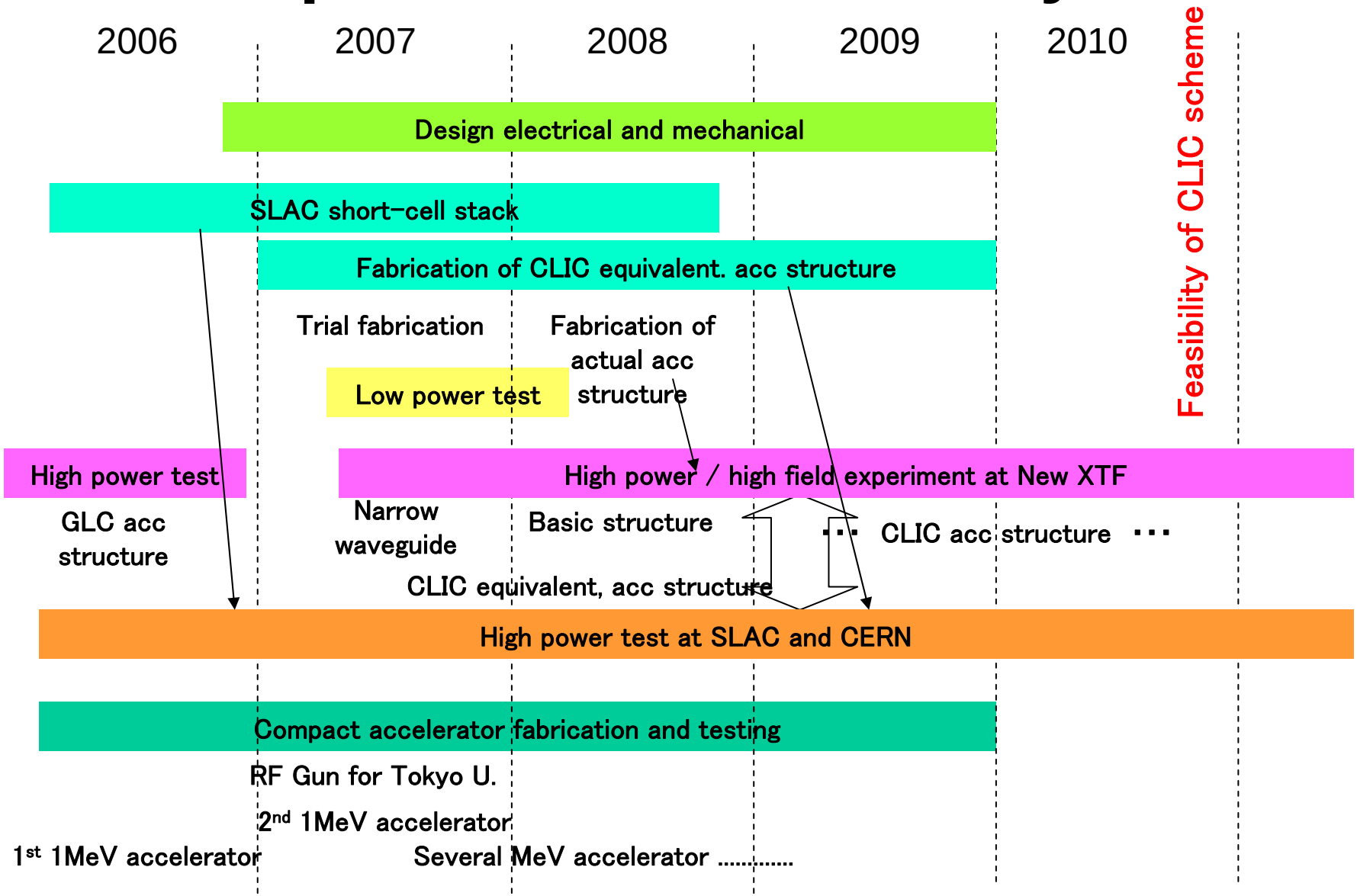
Mitsuo Akemoto, Shigeki Fukuda, Toshiyasu Higo,
Noboru Kudoh, Shuji Matsumoto, Hisamitsu Nakajima,
Kazue Yokoyama, Mitsuhiro Yoshida

(Accelerator Research Laboratory)

Yasuo Higashi, Hiroshi Kawamata, Toshikazu Takatomi, Kenji Ueno

(Mechanical Engineering Center)

Global plan of X-band activity at KEK



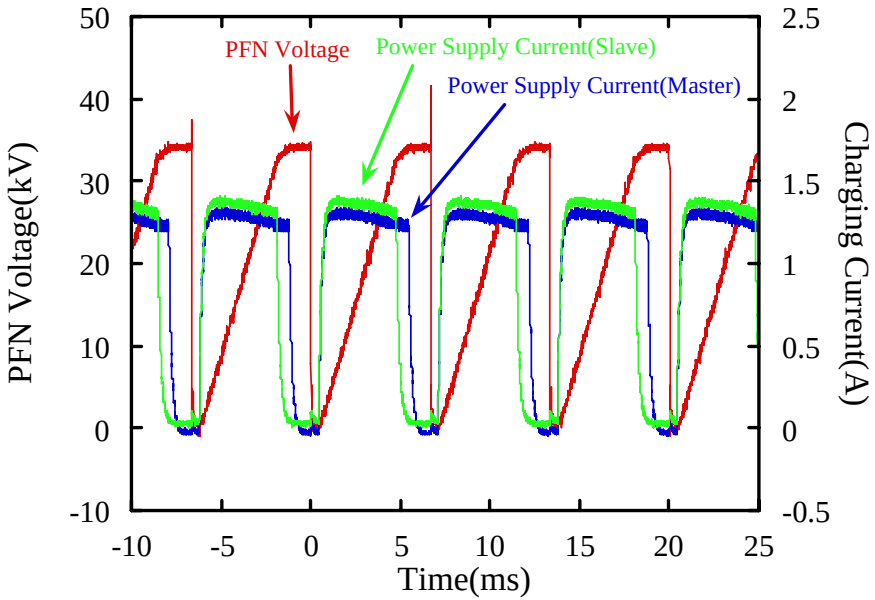
Legacy of GLC X-band

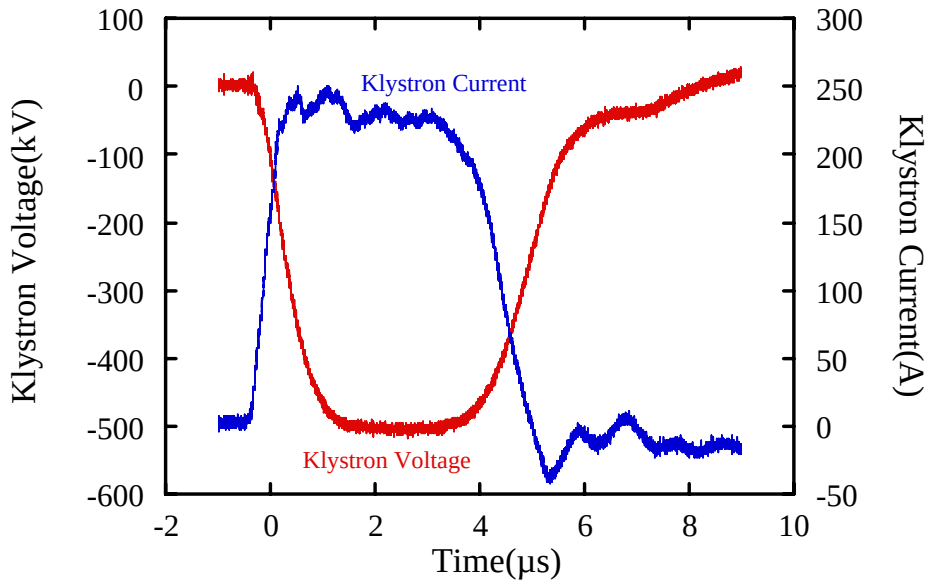
Main items we preserved.

- Modulators
  - 1-kly drive, 2-kly drive
- Klystrons
  - 3 PPM's to be used, 1PPM to be rebuilt
- Accelerator structures
  - CZ 30cm-long, DS &DDS 60cm long
- Waveguide components
  - WR90, low-loss (SLAC)

XTF Modulator (test result and operation)

Klystron : 1, Inverter PS : 4, Repe. Rate : 150 Hz, Vpfn : 35 kV





Pule width : 4.5 μs
Flat-top width : >1.6μs(±0.5%)
Rise time : 0.9μs(10-90%)
Pulse voltage stability : ±0.15%

- Two modulators have been operated stably.
- Modulator operation driving two-klystrons will be done in new XTF.

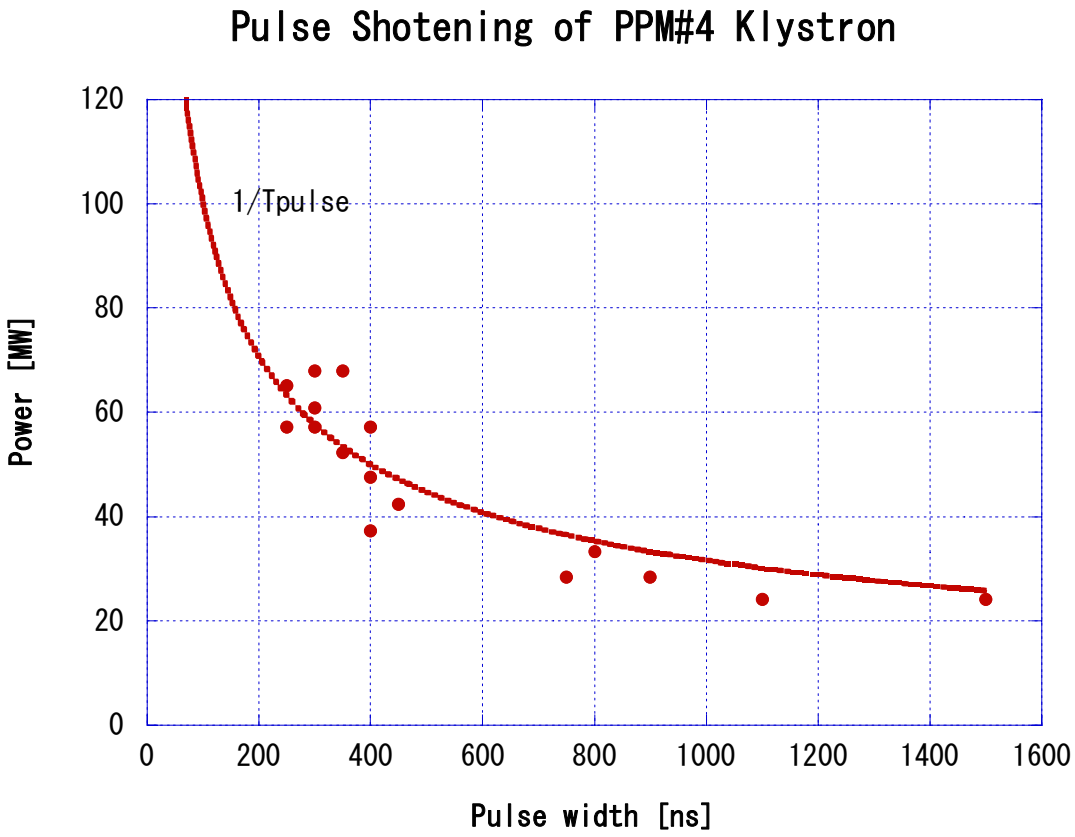
PPM X-band Klystron for XTF

Operation Parameters for XTF

• Operating Frequency	11.424 GHz
• RF Pulse Width	0.5 μs
• Peak Output Power	50 MW
• Beam Voltage	460 kV
• Repetition Rate	50 pps
• Efficiency	43 %

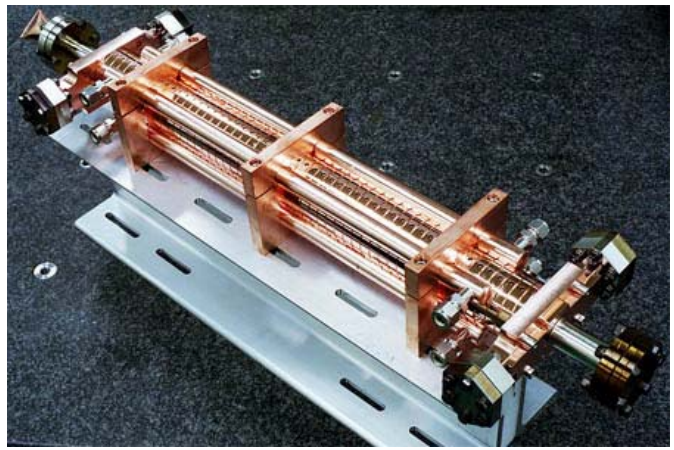
•The klystrons have been developed as prototypes of the GLC 75MW klystron.
•4 klystrons are alive.
•2 klystrons waiting for New XTF and 1 klystron running at Klystron Test Stand.
•We plan to rebuild 1 klystron in this FY.

Klystron performance

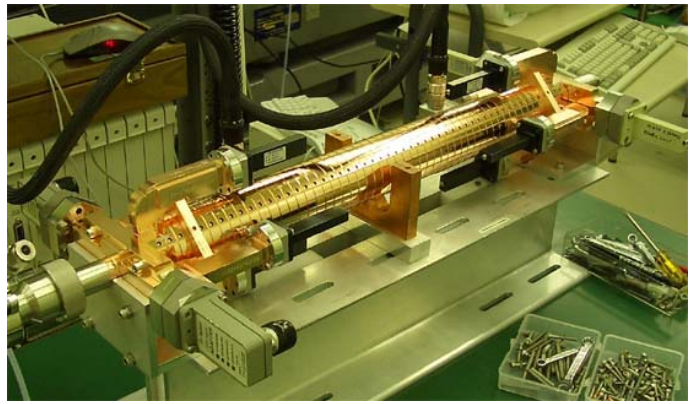


Recent 60cm structures made by KEK and tested at old XTF

- KX01(DS)
  - Tested up to 75MV/m, 400ns in 1200 hrs



- KX02(DDS cells)
  - Tested up to 85MV/m, 400ns in 400hrs
- KX03(DDS & HOM damp)
  - Tested up to 75MV/m, 400ns in 400 hrs



X-band related facilities

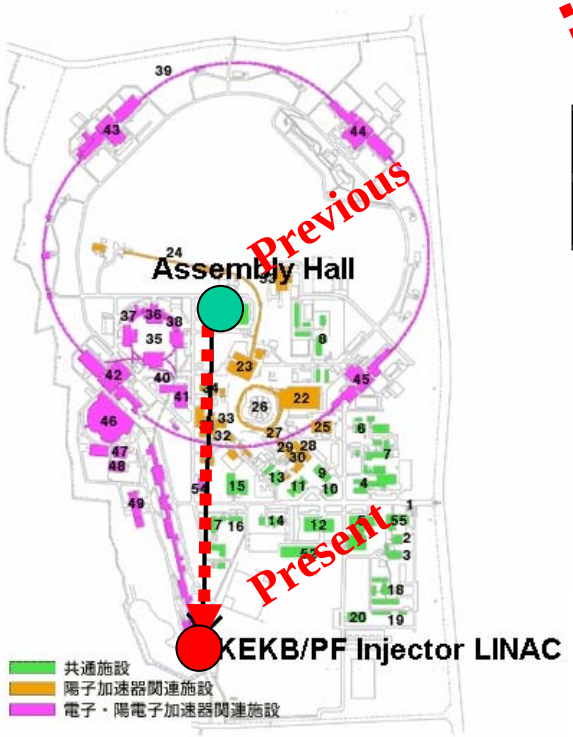
One in operation

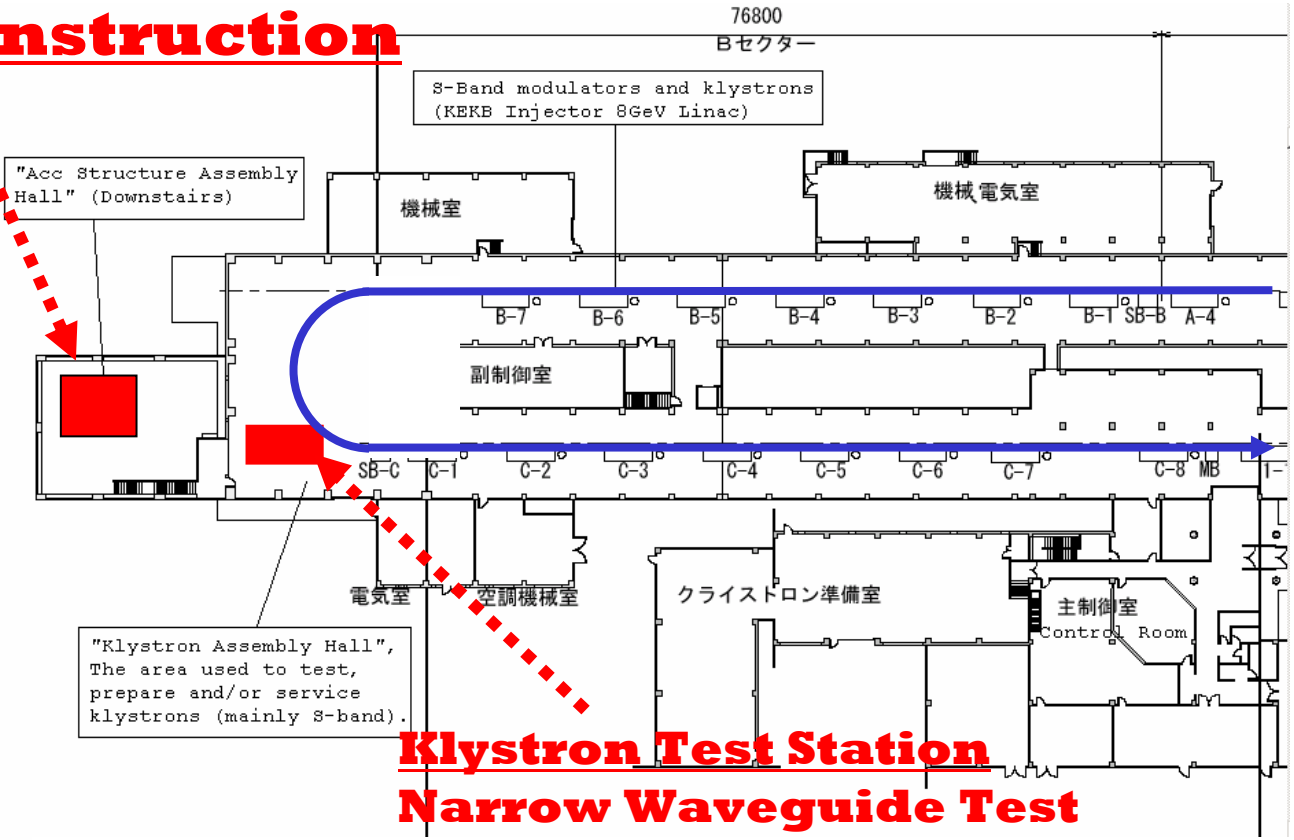
and

One under development

“New” X-band Test Facilities

New XTF under construction

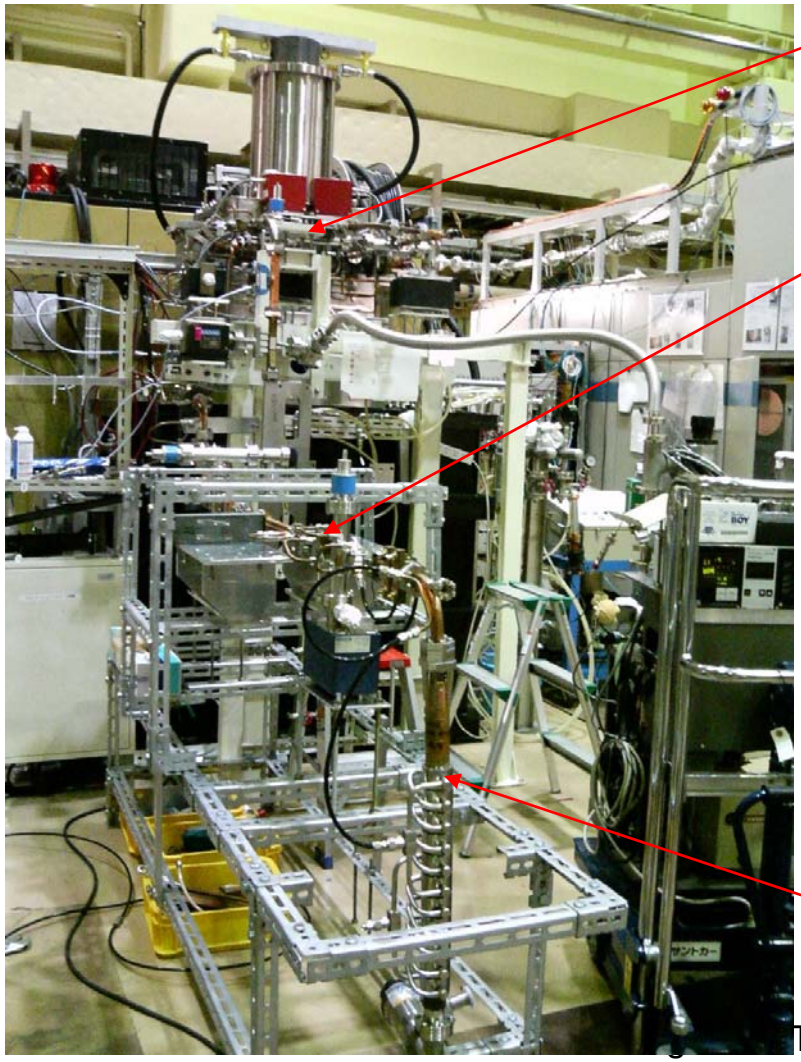




Plan view of KEKB Injector

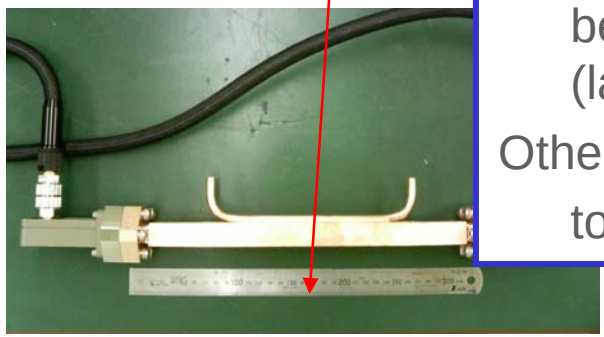
Klystron test stand

On-going high field test



PPM Klystron

Narrow waveguide in 5mm lead shield

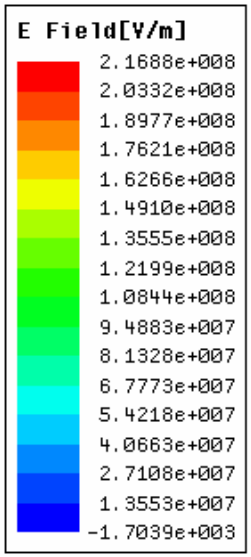


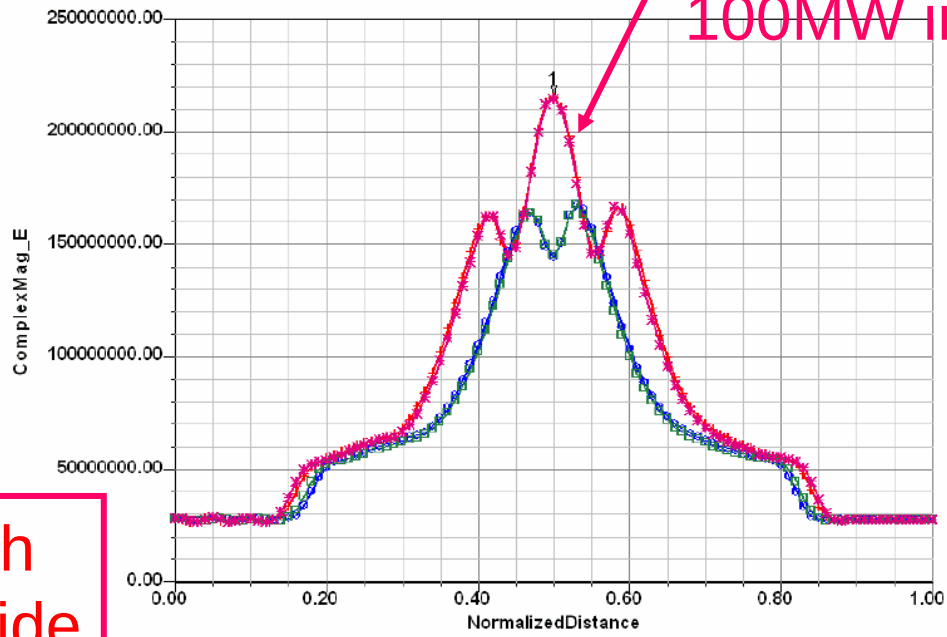
High Power Dummy Load

- Cu-002
  - tested at XTF and used for system startup (May)
- SUS-003
  - under test (June)
- Cu-004
  - being tested (later)
- Other samples
  - to be tested

Narrow Waveguide Design

Present design at
100MW input

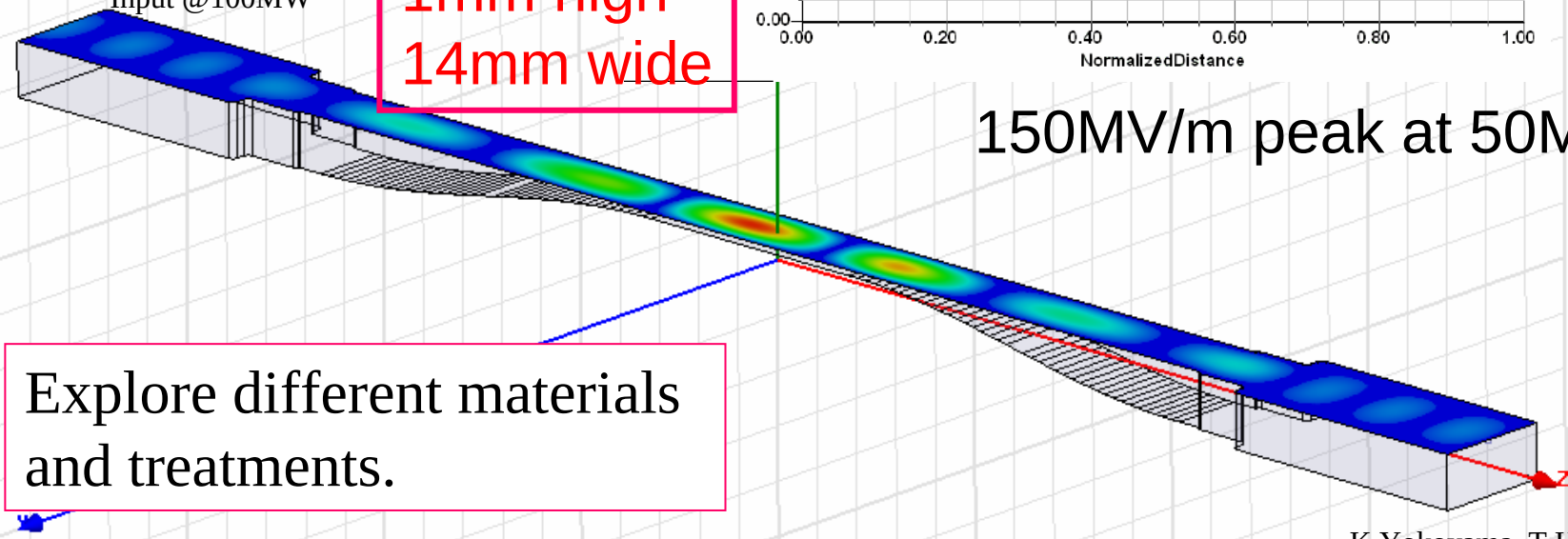




Input @100MW

1mm high
14mm wide

150MV/m peak at 50MW



Explore different materials and treatments.

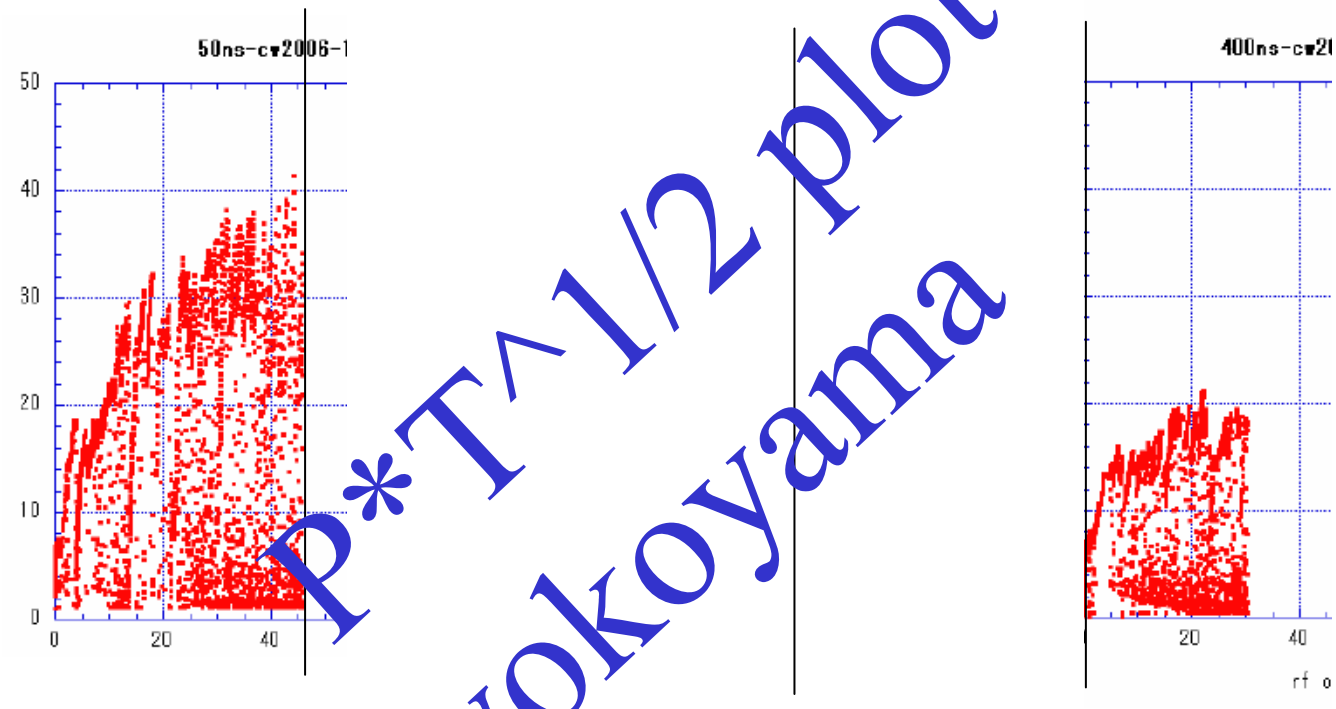
Experimental setup

- RF waveform by crystal
- Vacuum level by CCG
- BD detection by RF reflection and vacuum
- Acoustic sensors (SLAC)
- Plastic scintillators with PMT
- Pulse shapes were recorded as TDS oscilloscope view while stopping operation

Results in old XTF

50ns 100ns 200ns 400ns

MW



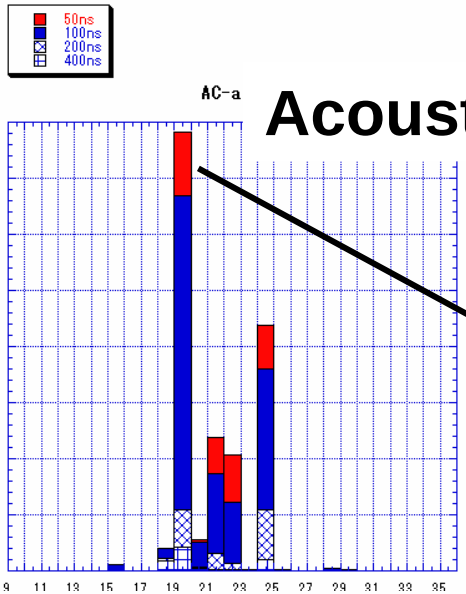
P*T^1/2 plot

yokoyama

~220hrs

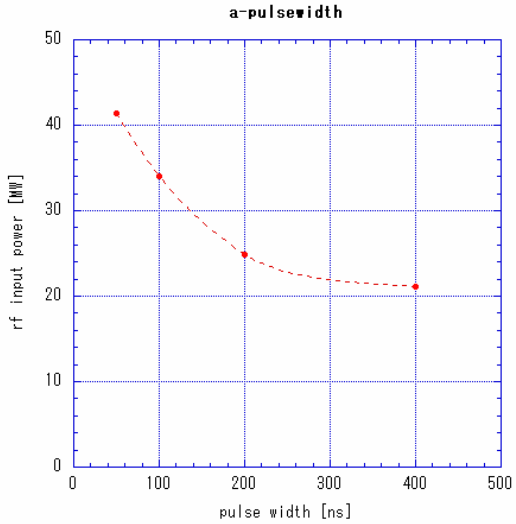
Breakdown Location

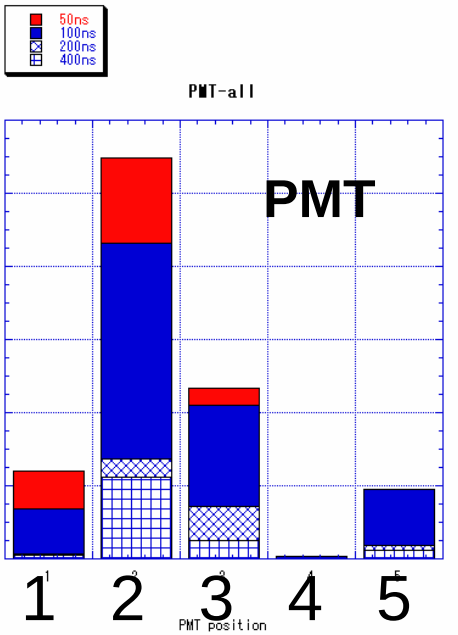
Observed BD Threshold was much lower than expected.



Acoustic

Area of frequent breakdowns



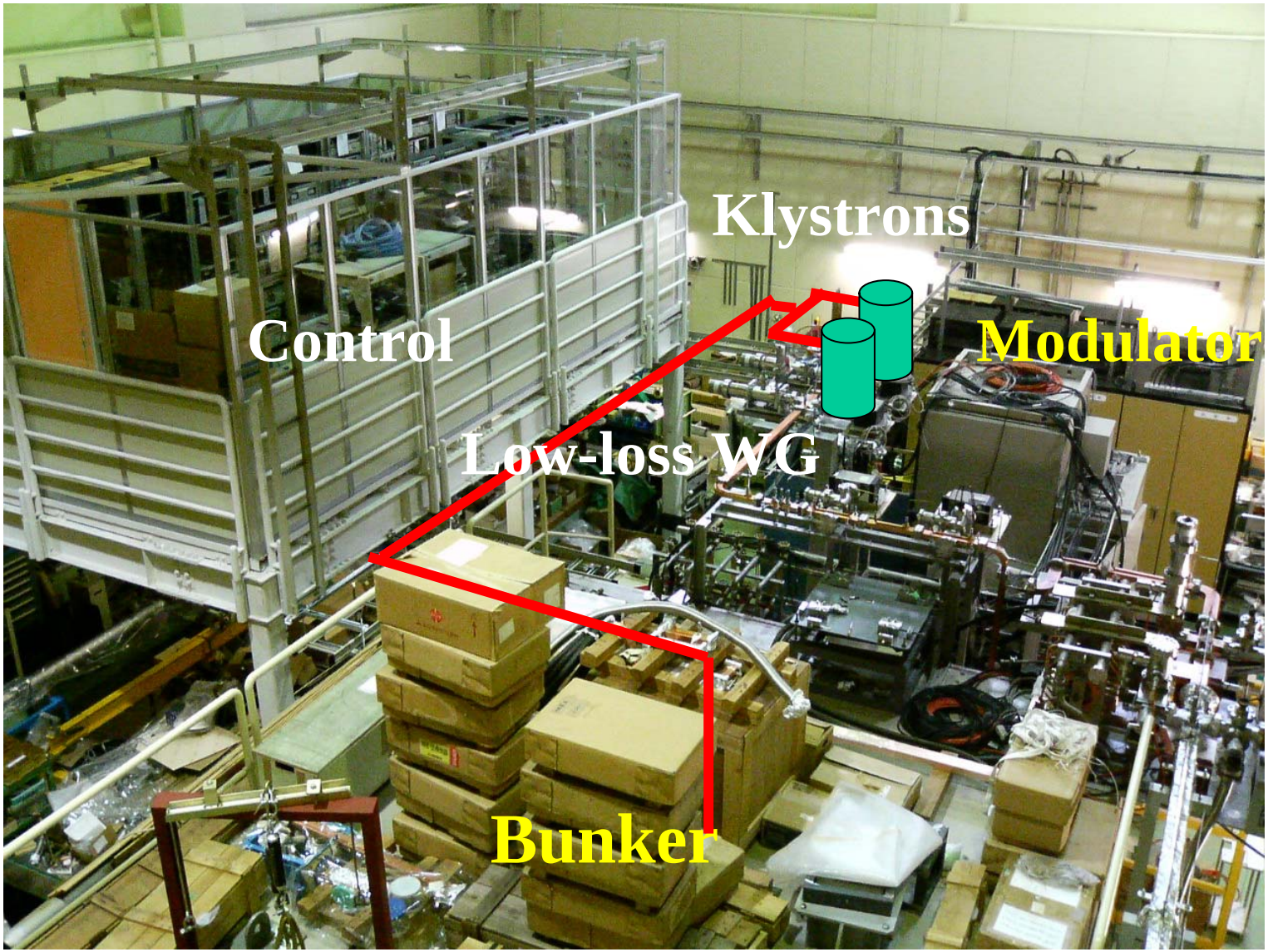


K.Yokoyama, T.Higo, N. Kudoh

Cu-002 after high-power processing

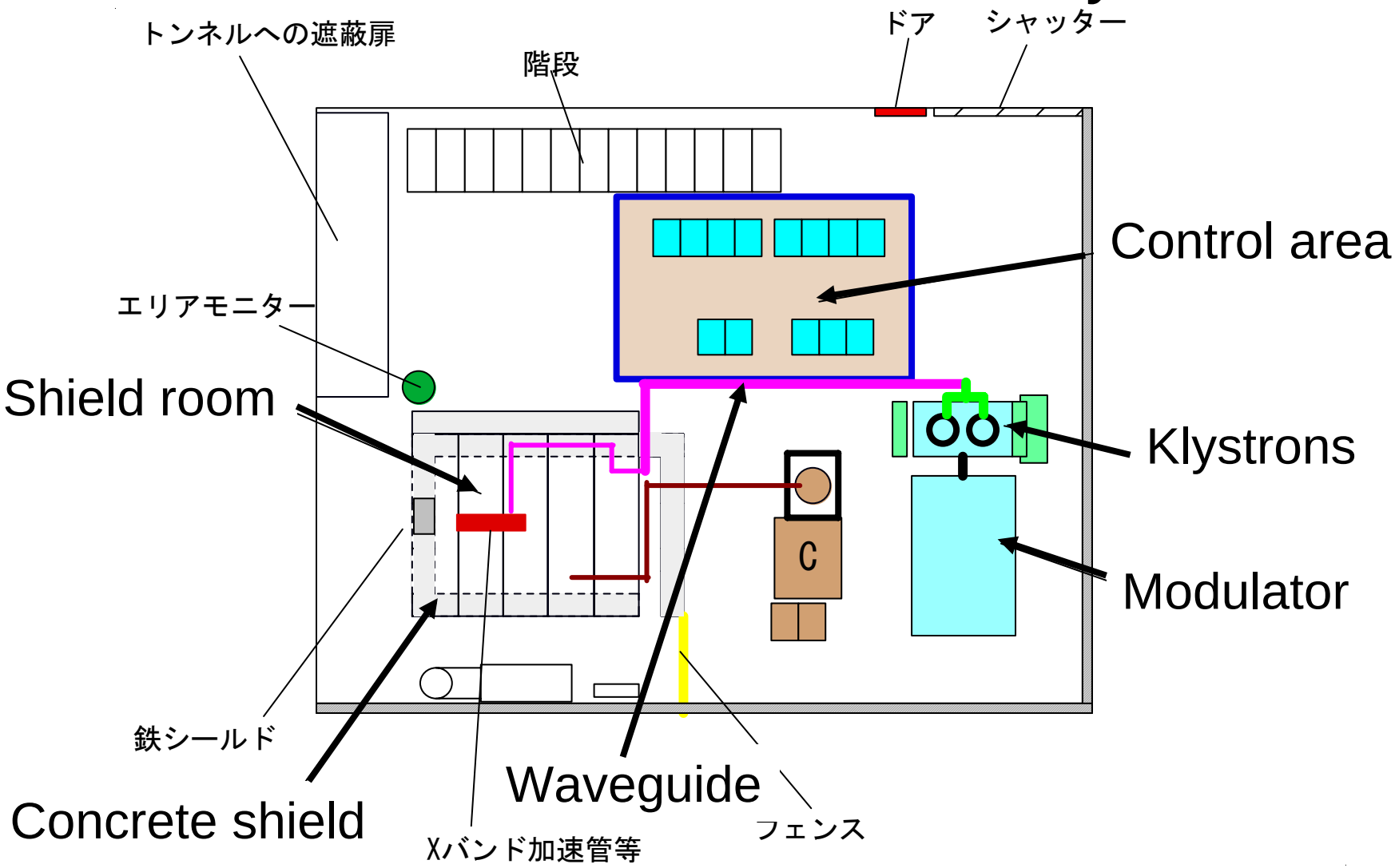
RF

New XTF



Configuration of new XTF

in accelerator structure assembly room



Features of the facility

(100MW, 400ns, 50pps), 24hr/day

50cm-thick concrete shield room

Control system adapted to KEKB Injector control system

- Data acquisition through LINUX and storage with EPICS

RF pulse shape recording for BD and preceding pulses

- Evaluation with stopping operation from the beginning
- Pulse-to-pulse evaluation to be done later (dep. on money)
- Phase measurement not yet planned

Dark current evaluation

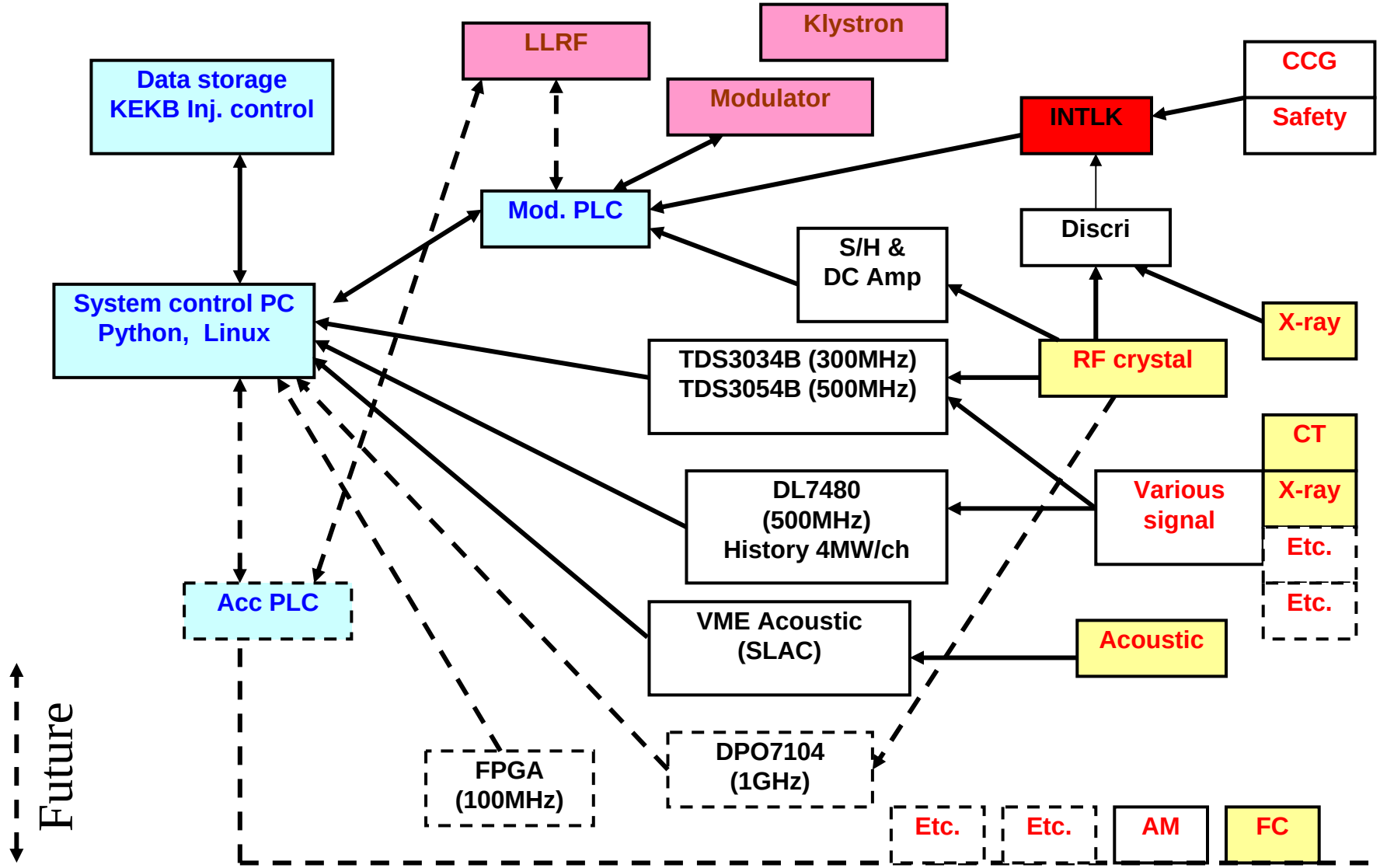
- Charge by FC, pulse shape with CT and energy by analyzer magnet

Acoustic measurement (developed by SLAC)

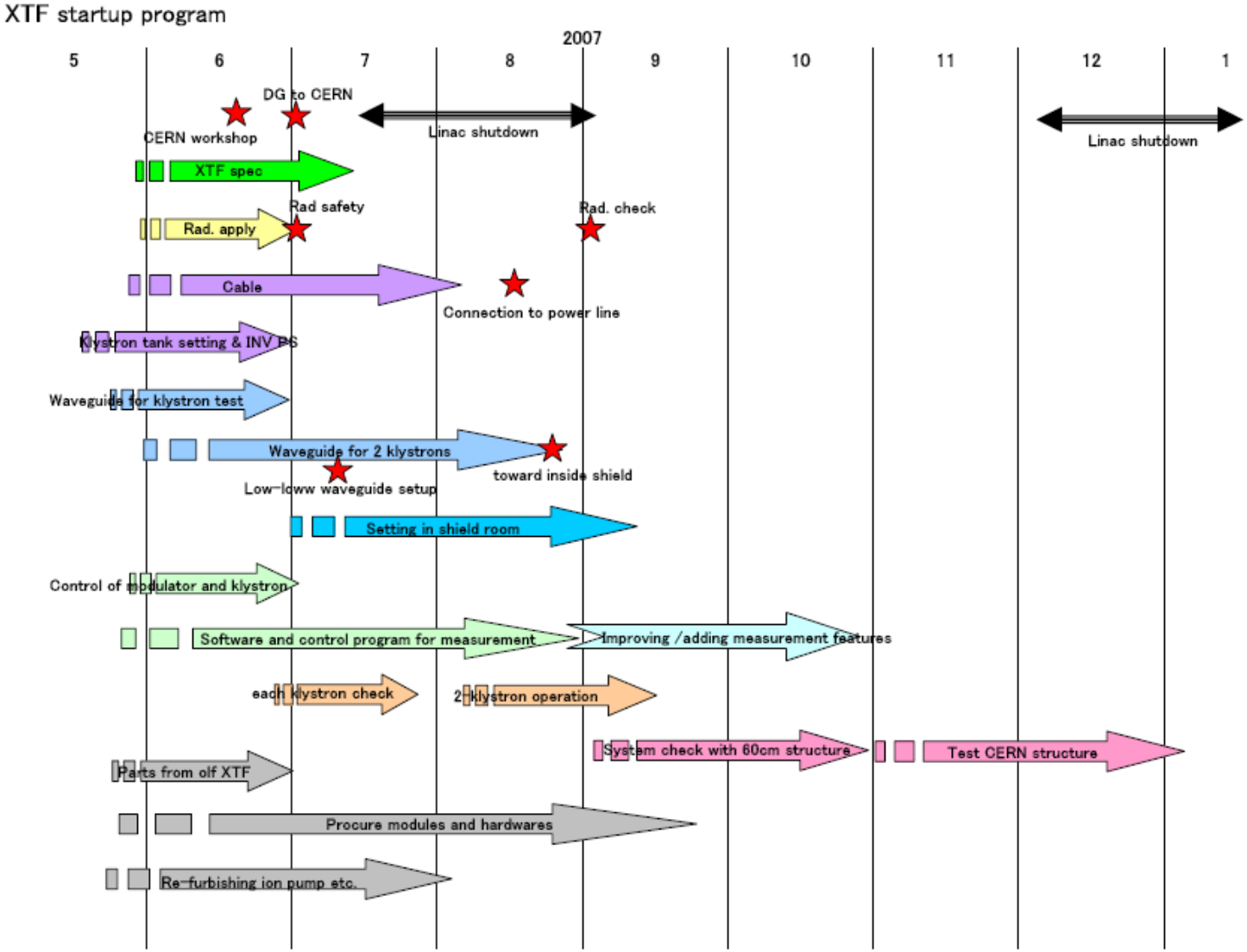
X-ray measurement with small plastic scintillators with PMT's

Q-mass monitoring

New XTF control system



New XTF Schedule in 2007



Construction of New XTF

1. Startup with each klystron will be in July.
2. Operation with two klystrons combined will be after linac summer shutdown.
3. Sophisticated measurement system will be established in fall.
4. System check by existing KEK structure.
5. High power test of CLIC structure late this year.

Mode of operation in these new facilities

- 24-hours continuous run during linac operation with taking care of the system by linac operators. More than 5000hrs will be possible.

- Try to make the similar continuous operation during shutdown period, but subject to the X-band operator available.

Need further implementation?

We will start without the following features.

- Pulse-to-pulse analysis?
  - Energy deposit of each pulse
  - Apply scheme of linac monitor group using oscilloscope with fast communication
- Phase information?
- Power more than 100MW?
- Longer pulse than 400ns?
- Higher rep-rate than 50Hz?
- Automatic with variable width & rep-rate?
- Clean system and environment?
- Baking at much higher than 200C?
- Anything more??

DC High voltage breakdown experiment at Saitama U.

- Pulse with 80kV, 60microsec.
- 500-times BD treatment
- In-situ surface evaluation by AES, XPS
- In-situ baking
- Diamond-turned copper buttons were tested
  - H_2 furnace treatment was found effective to speedup conditioning
- But now we are stopping X-band related activity

Fabrication facilities

Mechanical engineering center

Present and future direction

- Description of MEC
  - Staff
  - Machines
  - Projects
  - Etc.

More description by Ueno

- Pictures
  - Chemical treatment
  - Furnace
  - Machining
  - Etc.

Pictures??

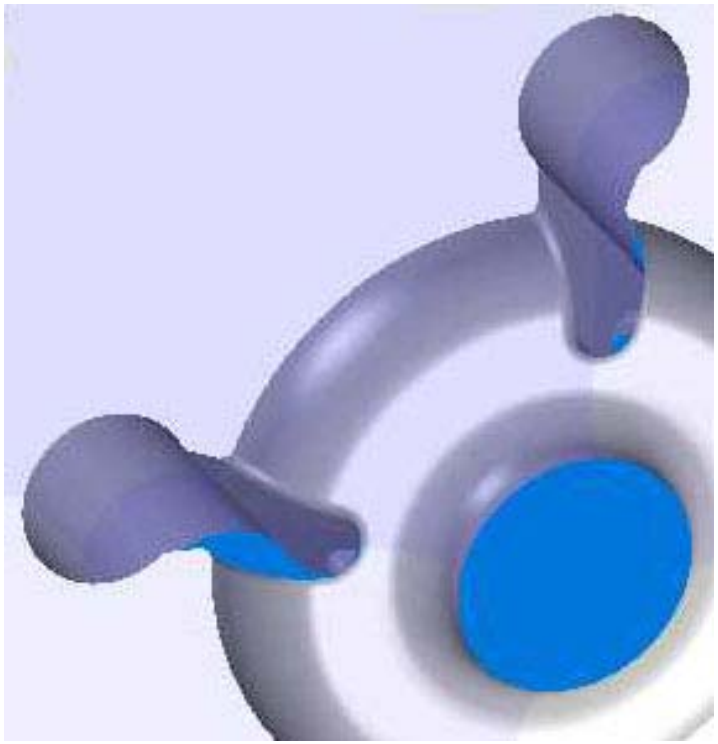
Recent activities
related to accelerator structure

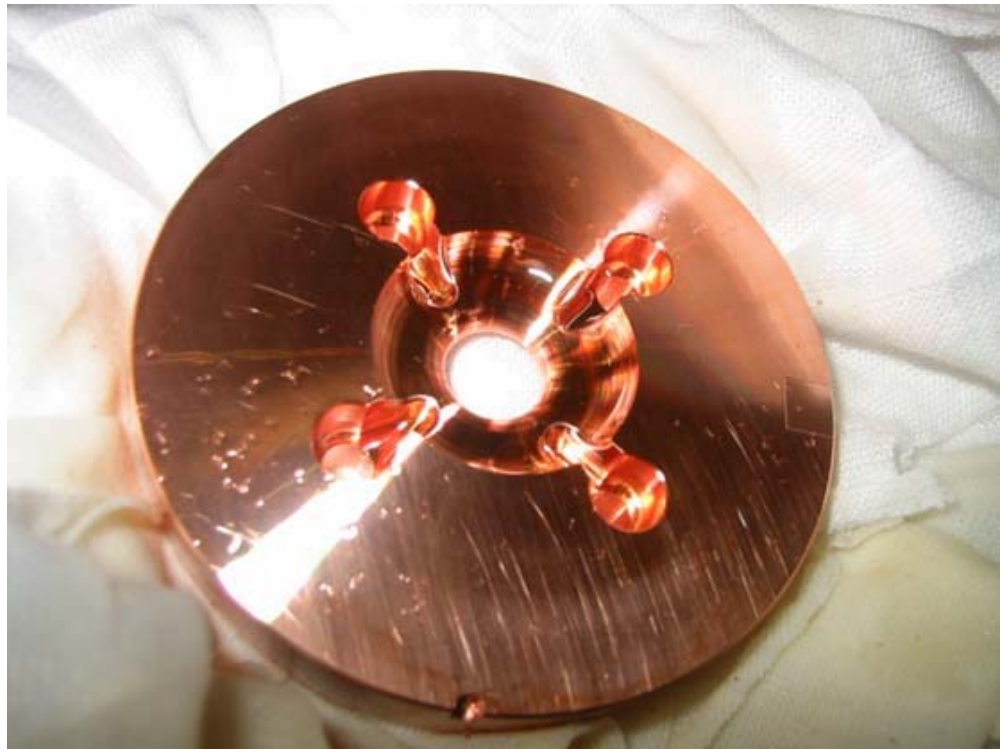
- Turning
  - Rough~medium machining is done by outside vendor, followed by diamond turning at KEK.
- High-precision milling
  - Pilot fabrication study of RDDS was done at Yasuda co.
- Furnace
  - Mostly hydrogen one, sometimes vacuum one
- Surface treatment
  - We developed a chemical treatment setup following SLAC recipe for diamond-turned copper

Mechanical machining

- 60cm structures
  - Milling ~several-micron by outside company
  - Add high-precision diamond turning ~1microns at KEK
- Boosting milling capability for CLIC
  - We have a precision milling machine ~1microns but the spindle not very rigid and with limited-speed ~5000rpm
  - We have ordinal-precision machines ~50microns
  - Further development work was performed with a company, Yasuda co., a leading milling machine maker.
  - We want to develop a milling capability suitable to CLIC structures.

RDDS disk test fabrication by Yasuda co.





Done with ball-end mill.
Smooth connection from flat through round ridge to key holes.

Surface treatment around KEK

- Chemical rinsing setup
  - Following SLAC recipe for diamond-turned copper
  - Apply surface treatment developed for good vacuum
- Particle free and possibly chemically clean
  - Learn from ILC
- STF (in future)
  - EP facility now being developed for ILC

Further studies for good surface

Following items will possibly be studied.

- Material
  - HIP?, Single-crystal?
  - Vacuum melted Mo?
- Cleaning
  - Keep present chemical treatment setup
  - We will explore better surface treatment method
    - Mega-sonic rinsing
    - Semi-conductor wet cleaning solution
- Surface treatment at high temperature
  - Evaluate high-temperature ~500C baking effect
  - Hydrogen furnace
  - Vacuum furnace with Ti shielding
  - Compare heat treated (800~1000C) to non-treated

Collaboration with Kobe Univ.

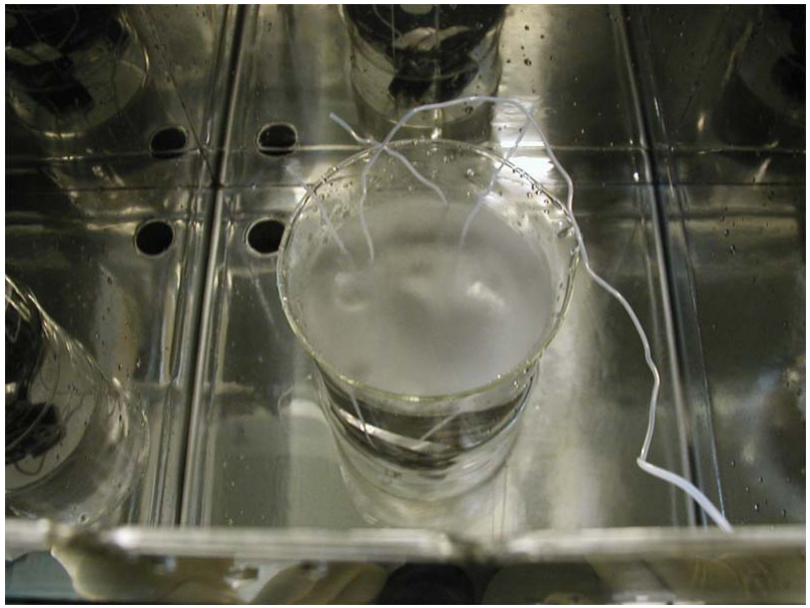
Exploring machining techniques for accelerator structure

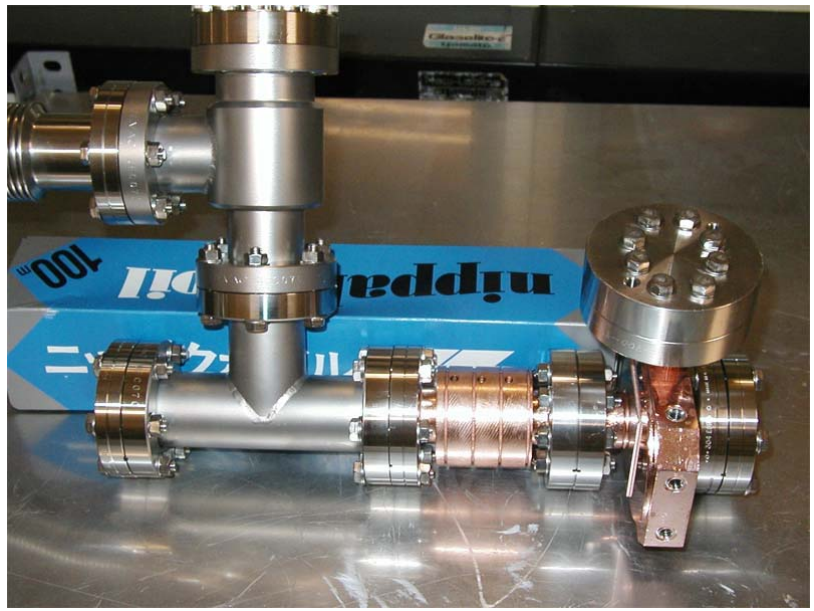
- Fine fly cutting of refractory metals.
  - Mo narrow waveguide will be made.
- Diamond tool
  - Milling with a vibrating tool in ultra-sound regeme.
- Long period is needed now for milling large area.
  - Need evaluation of effectiveness.
  - Need speed-up for practical use?

Trials to reduce FE and BD

- Higashi-Valery (KEK-SLAC) line
  - single-cell and three-cell cavity for high field at SLAC.
- Some trials mentioned before have started:
  - Megasonic rinsing
  - Some rinsing solution
  - Vacuum baking of closed volume

2nd Single cell SW structure preparation





A-02 solution + Megasonic cleaning

960kHz, 600 W, 5 minutes operation

Ultra Pure Water

All parts were applied megasonic cleaning

Assemble envelopment: Class 10

No vacuum leak

300 degC baking, period : 5days

Still needs to improve the cleaning techniques

Overall testing plan

How to establish high gradient

In a practical accelerator structure

- We learned from SLAC-KEK program for GLC
  - Several-tens of structures were tested.
  - Still yet to be understood how the final performance was determined.
  - Design parameters, details of the preparation processes, all these should be interrelated.
  - We need more statistics for important evaluation step.

- Take the spirit of the S0 task force in ILC
  - S0 is evaluating the same cavity in three regions. Three cavities made in each region are evaluated three times in each region.
  - Important decision should be done with enough statistic.

X-band activities in 2007

- Discuss with CERN and SLAC on collaboration
- High-field test with narrow waveguide
  - –Cu with various surface condition
  - –Comparison among materials, Cu, SUS, Mo, Ti, ….??
- High-field test at new XTF
  - –Establish high-power test system
  - –Accelerator structure test
- Test fabrication of CLIC structures
  - –Acquire the experience of CLIC design
- Fabrication of cavities for test at SLAC KLY lab.
  - –Surface treatment method
- Fabrication of compact accelerator
  - –1MeV accelerator, RF Gun, etc.

XTF plan in 2007

- KLY test station (50MW level)
  - –Apr.-July: Narrow waveguide high-field test
  - –Summer~: Continue waveguide components tests
  - –Jan.~: Rebuilt klystron test

- New XTF (100MW level)
  - –July-Aug.: Check two klystron operation
  - –Sept.~: Operation with combining two klystrons
  - –Oct.~: Startup high field study system with an old GLC structure
  - –Nov.~: High-field test of CLIC-related structure
  - –As needed: Narrow waveguide test, single-cell test, etc.
  - –Welcome any high power test plan

KEK stance for X-band CLIC

- Three main items to pursue
  - High power test of structures.
  - Fabrication of structure for CLIC design.
  - Study basic high field and related surface issues.

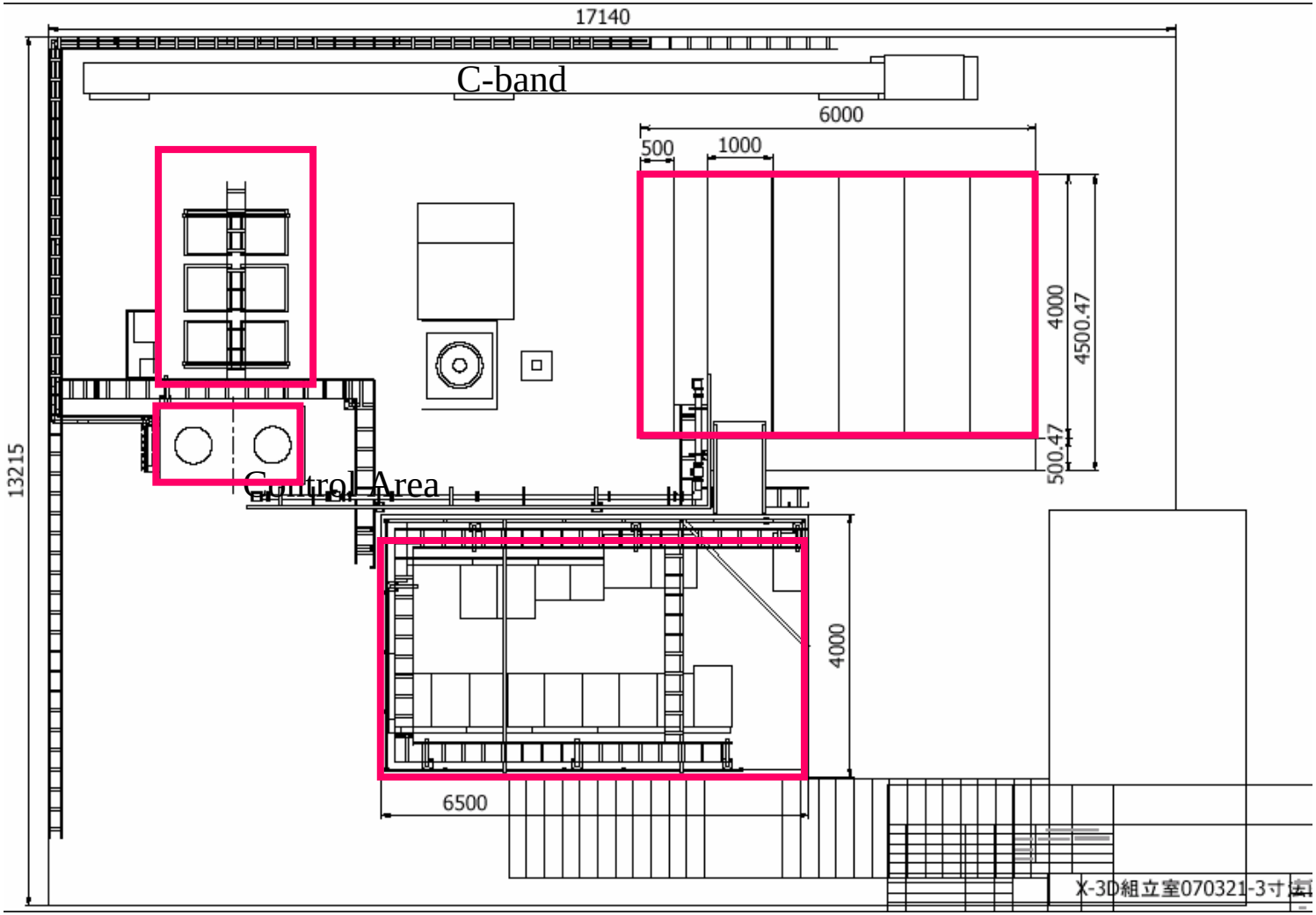
- Funding and manpower
  - We need to get competitive funding.
  - We try to organize more staffs.
  - We try to extend formal budgetary support from KEK by identifying our study items as KEK's acknowledged work.

Appendix

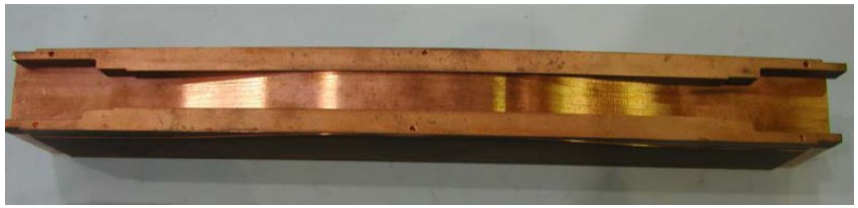
RF components

- Components were made by
  - KEK: Load, VAC port, etc.
  - Japanese companies: DC, 3dB, etc.
  - BINP, Russia: Load, DC
  - SLAC: Low-loss WG, Load

New XTF


17140
C-band
6000
500
1000
4000
4500.47
500.47
13215
Control Area
4000
6500
X-3D組立室070321-3寸法

Fabrication



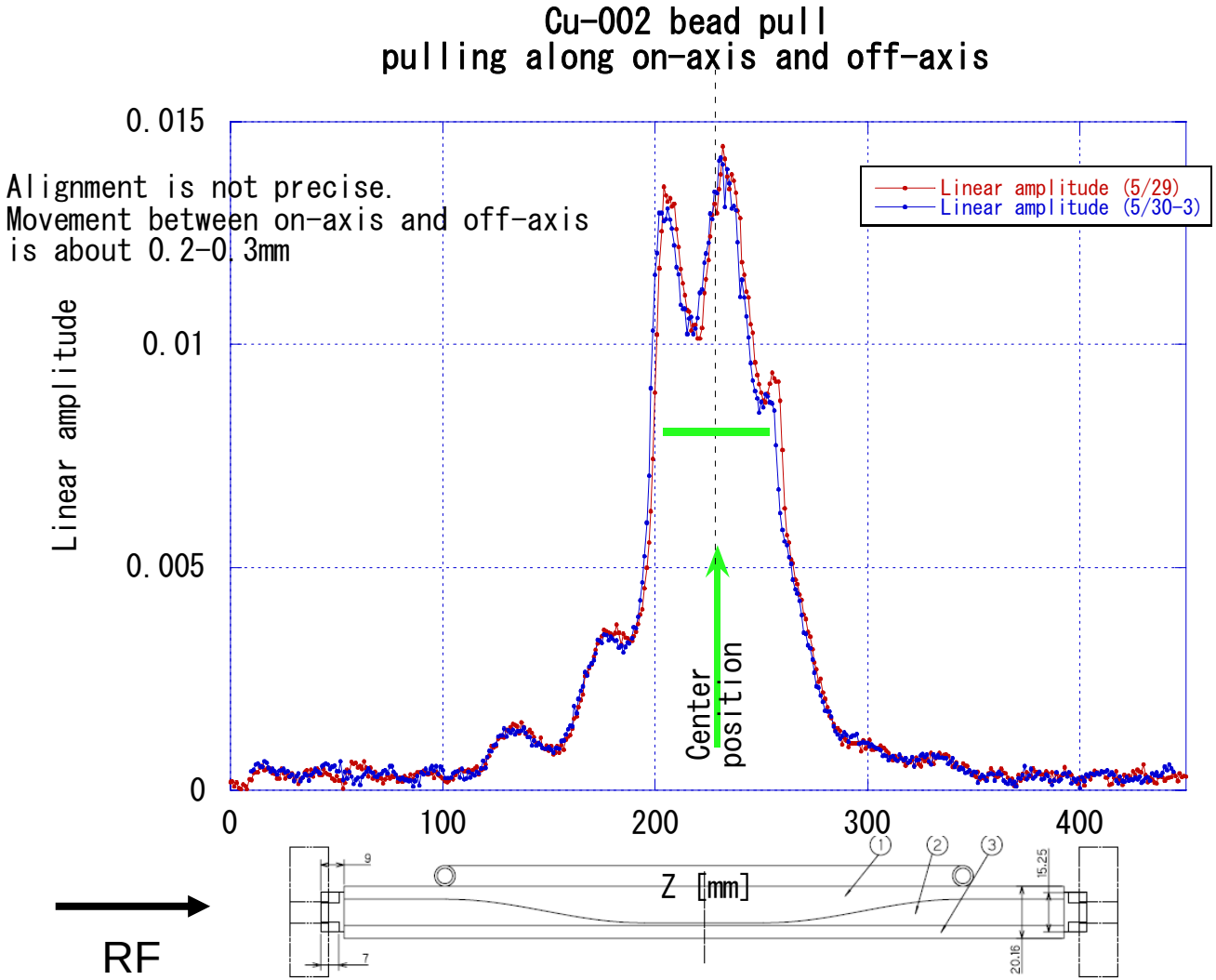
OFC class 2

Hydrogen brazing

Wirecut and milling

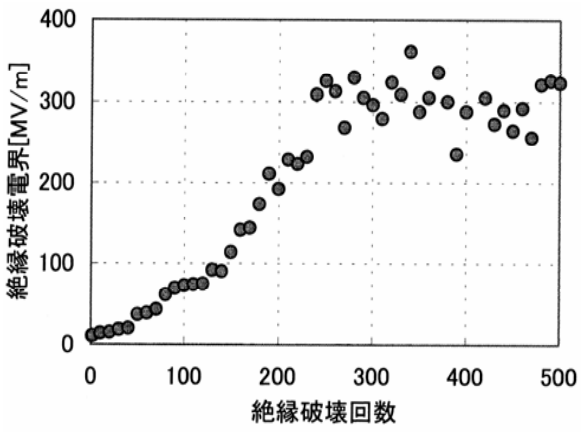
Acid rinsing at company

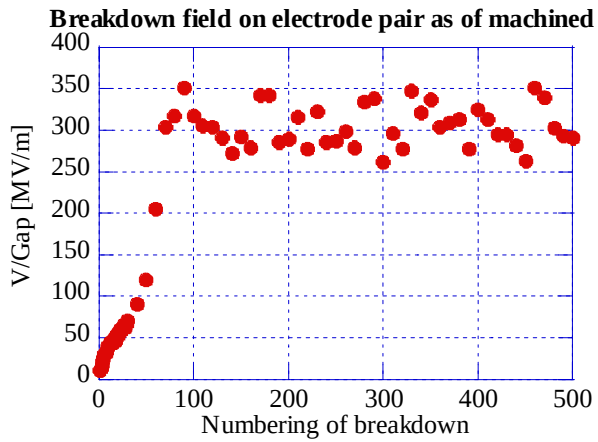
Bead pull along center of E-plane

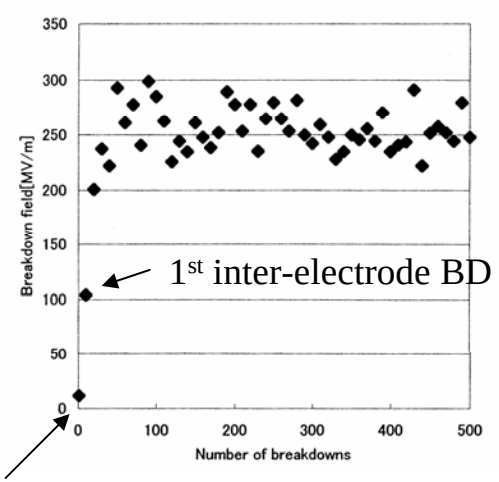


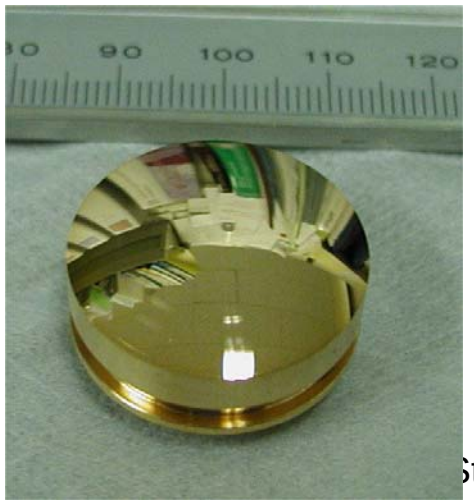
Pulsed DC-HV breakdown experiment at Saitama U. (now pending)

As diamond turned → + In-situ He sputtering → + Hydrogen brazing process









Importance of carbon on surface?

Need to understand high-temperature treatment.

Furnace of KEK

- Hydrogen furnace
  - H600 x ϕ300 (D5)
- Vacuum furnace
  - Size of 20cm order
- High-temperature treatment
  - Baking Higashi chamber
  - Double vacuum meter-size furnace (need refurbishing to awake)

Attempt on small amount of dark current and breakdown late at high gradient by removing particles and metal impurities on the cavity surface

removing particles and metal impurities techniques

- Using a semiconductor wet cleaning solution and Mega-sonic

Making thin Cu_2O layer on the cavity surface

- Vacuum baking at 500 deg.C

Keeping good cleanness at installation into the high gradient test setup

- Making class 100 environment

High gradient test structures

- Single and 3-cell SW structure

Test data analysis

- Needs statistically analysis

- Single cell : 7 structures, 3-cell : 5 structures should be required

Yasuo Higashi

Catalogs data of Si wafer cleaning by KANTO CHEMICAL CO. Ltd.
We use Frontier Cleaner W-A02

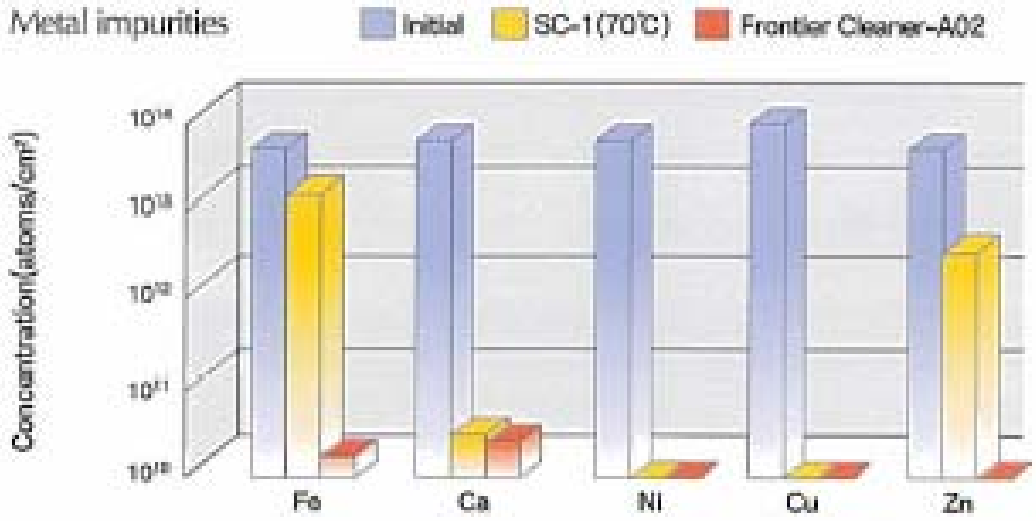


Fig1. Cleaning performance for metal impurities

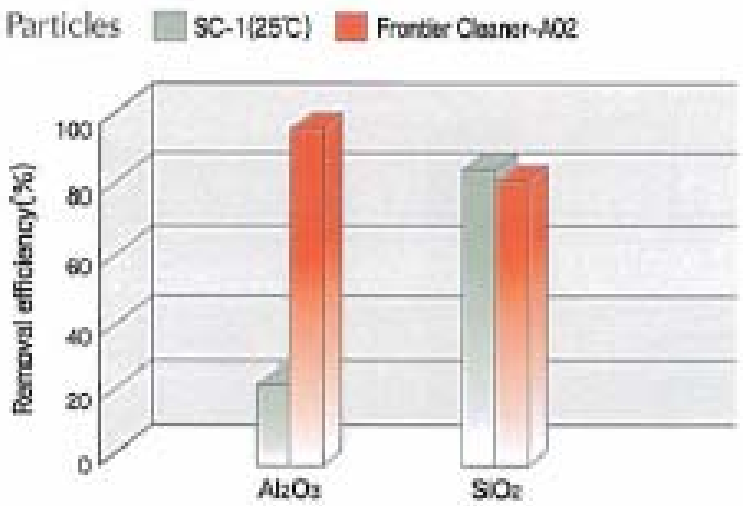
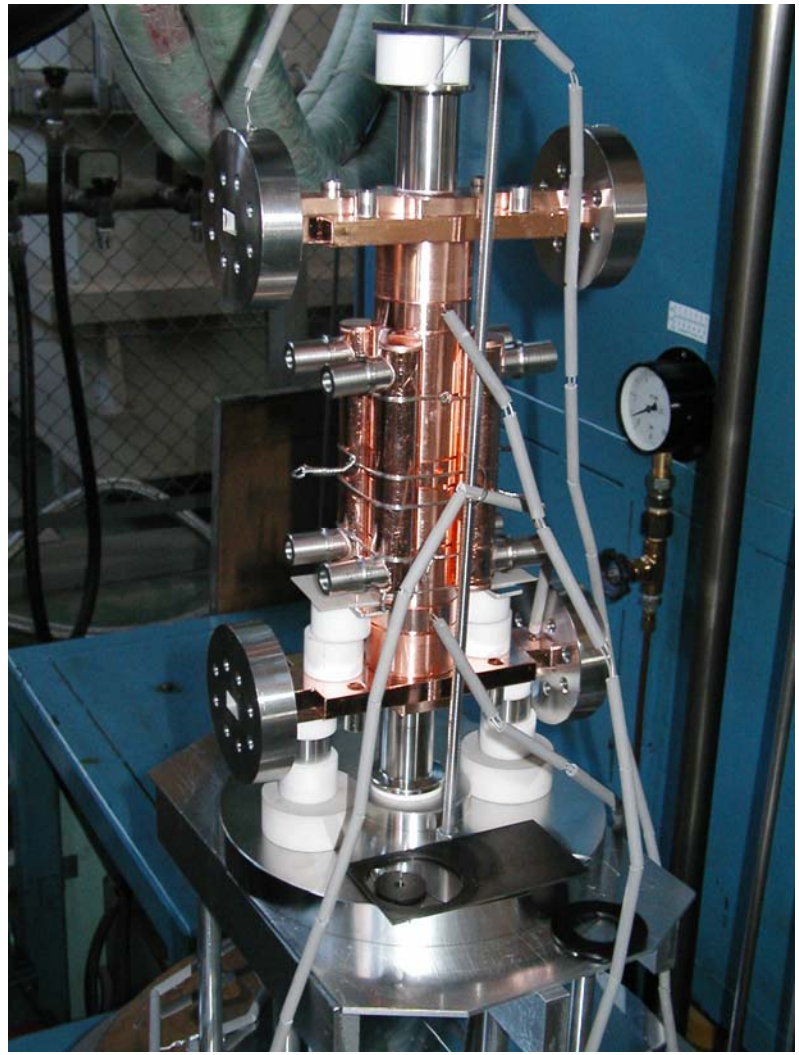


Fig2. Cleaning performance for particles

Short structure fabrication by KEK hydrogen furnace



Diamond turning

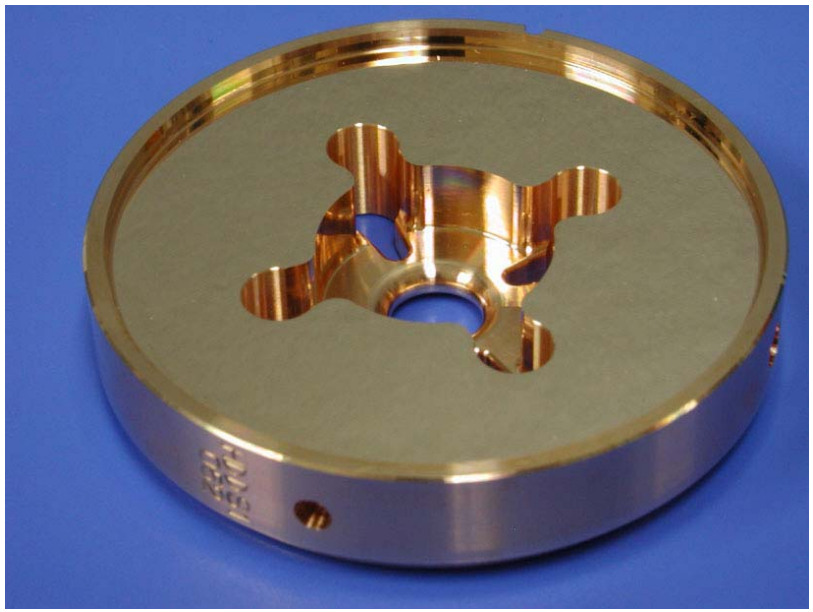
Diffusion bonding

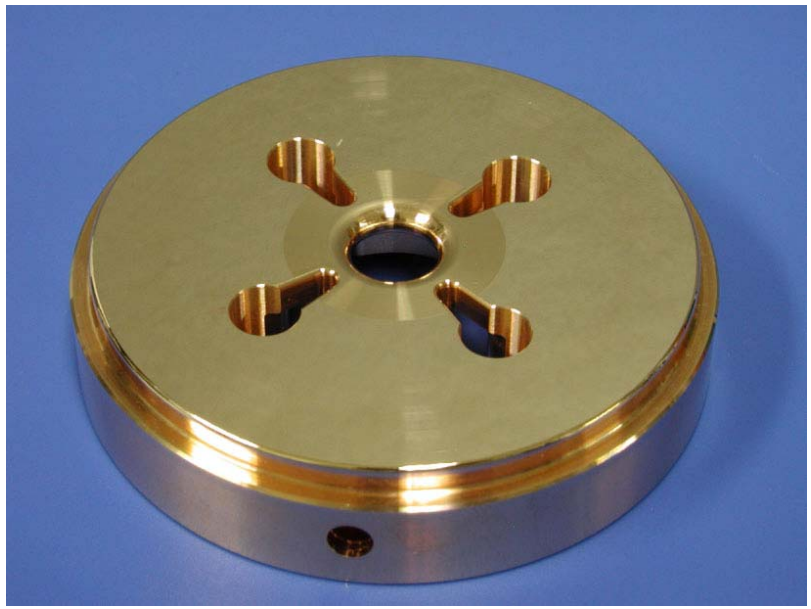
Brazing

Tuning

High power test

HDDS cell production

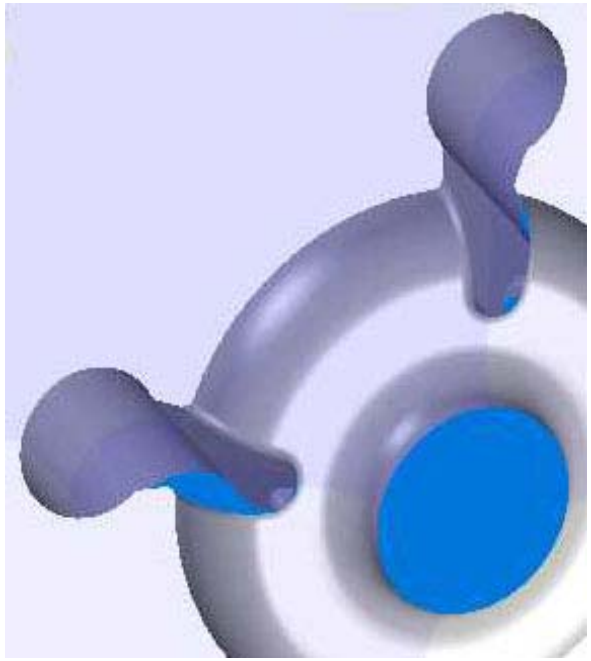


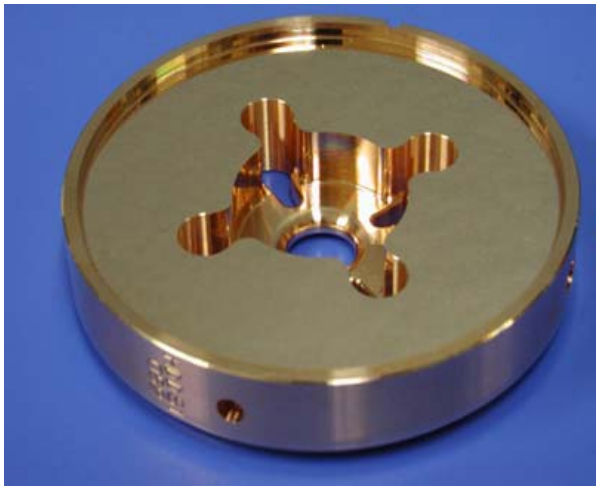


From RDDS1 and HDDS to RTOP

RDDS1
Symmetric disk
Sharp edge

RTOP

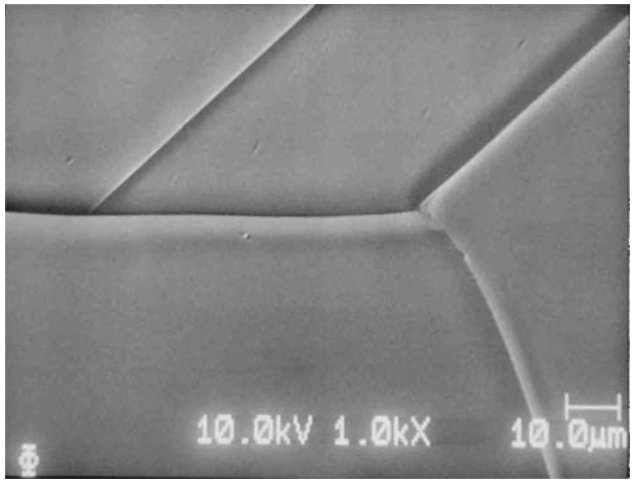




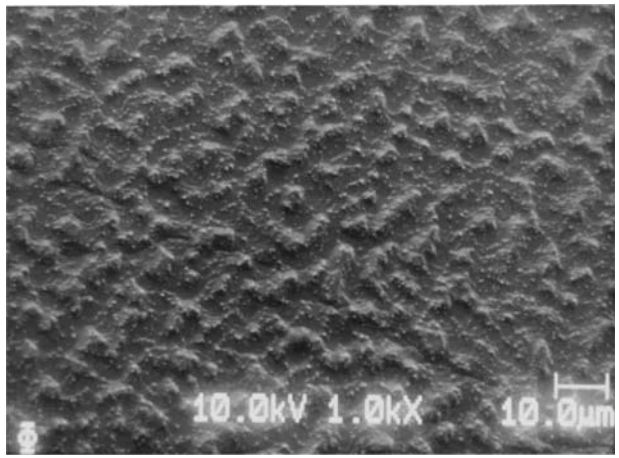
現HDDS
Cup shape
Rounded slits

Symmetric disk
Slit edge rounded

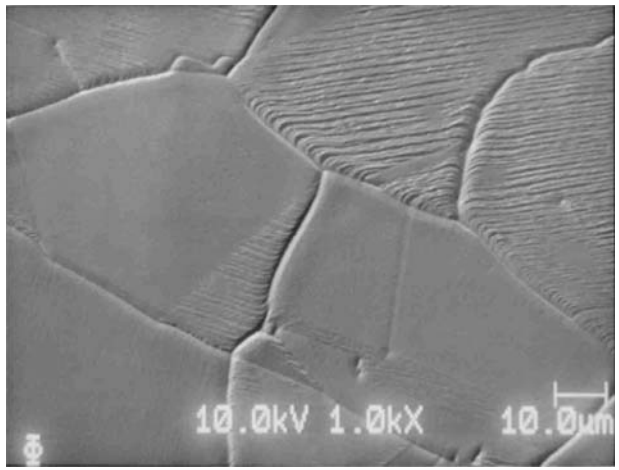
表面SEM像　高温炉処理での変化



ガス（水素）炉
スムージング



真空炉
むき出し



真空炉
銅キャップ下

良好な真空・適度なガスの効用・遮蔽の効用・・等を考慮して工程設計すること