X-band R&D at KEK

X-band RF Structure and Beam Dynamics workshop,
Dec. 1-4, 2008
Cockcroft Institute, Daresbury, UK

T. Higo, KEK

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- Nextef
  - T18_VG2.4_Disk #2 on-going processing
  - Possible extension of the facility
- Structure fabrication
  - Disk-damp and C10/CD10
  - Quad and chamber
- Basic study toward high gradient
  - KT-1
  - Thinkings
- Global plans
- Collaboration

High power test stations of KEK Nextef and KT-1

Nextef stands for NEw X-band TEst Facility with two klystrons.
KT-1 stands for Klystron Test station #1.

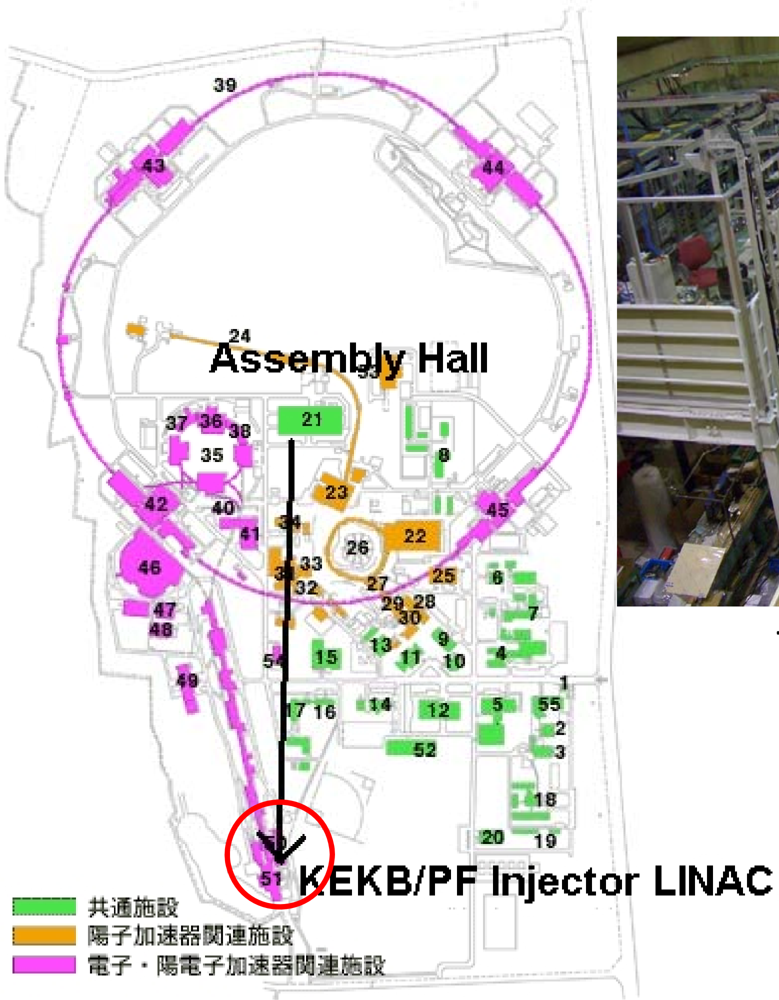
- Nextef

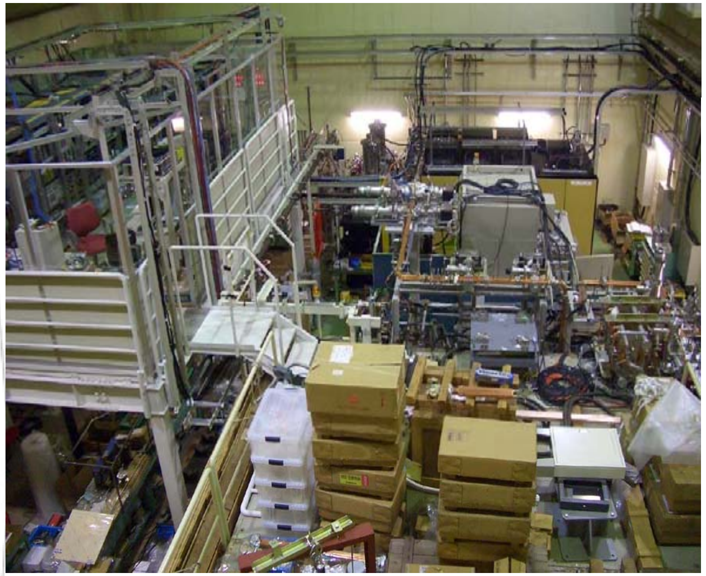
GLCTA facility was moved to the present place to make these facilities in 2007.
A 100MW high power station for the X-band accelerator structure tests.
CERN-SLAC-KEK collaboration on thigh gradient targeting 100MV/m level.

- KT-1

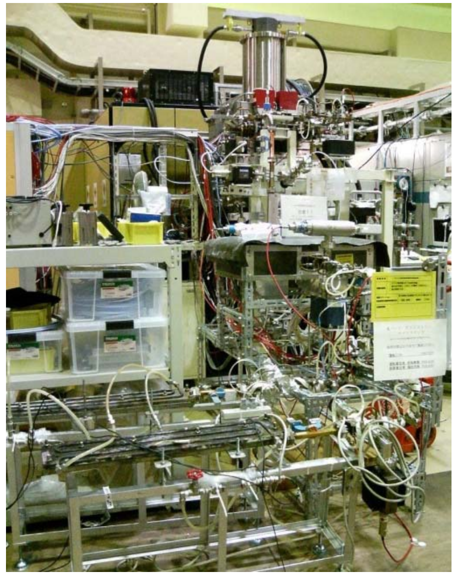
Small size fundamental studies on high gradient tests.
Such study as narrow waveguides are proceeded.

Nextef



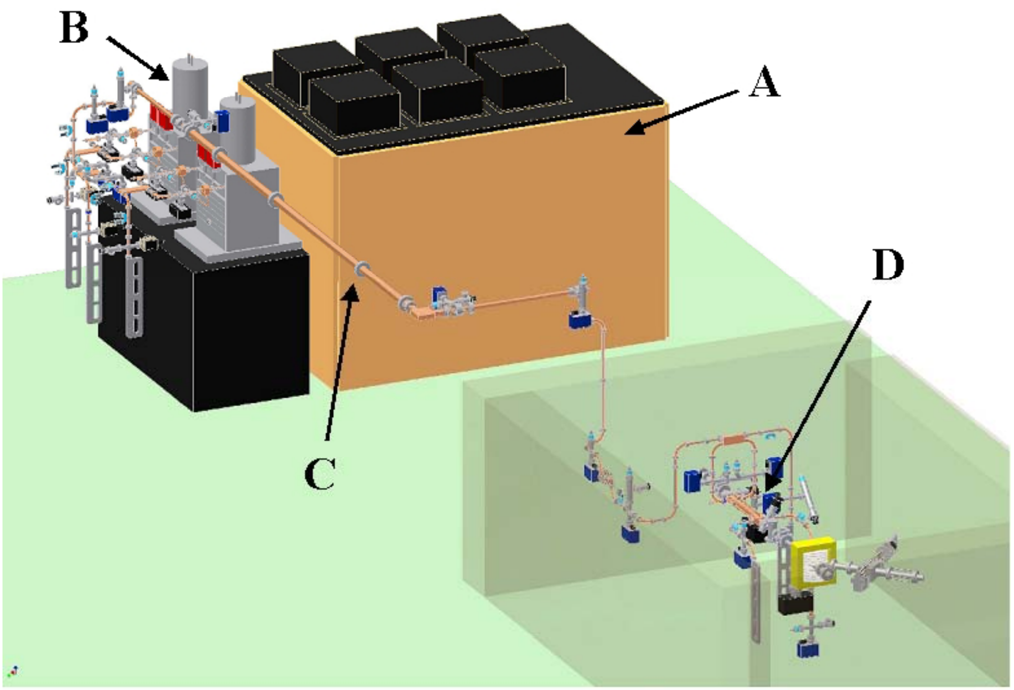


Two klystron facility
Nextef



One klystron setup
KT-1

Nextef Configuration

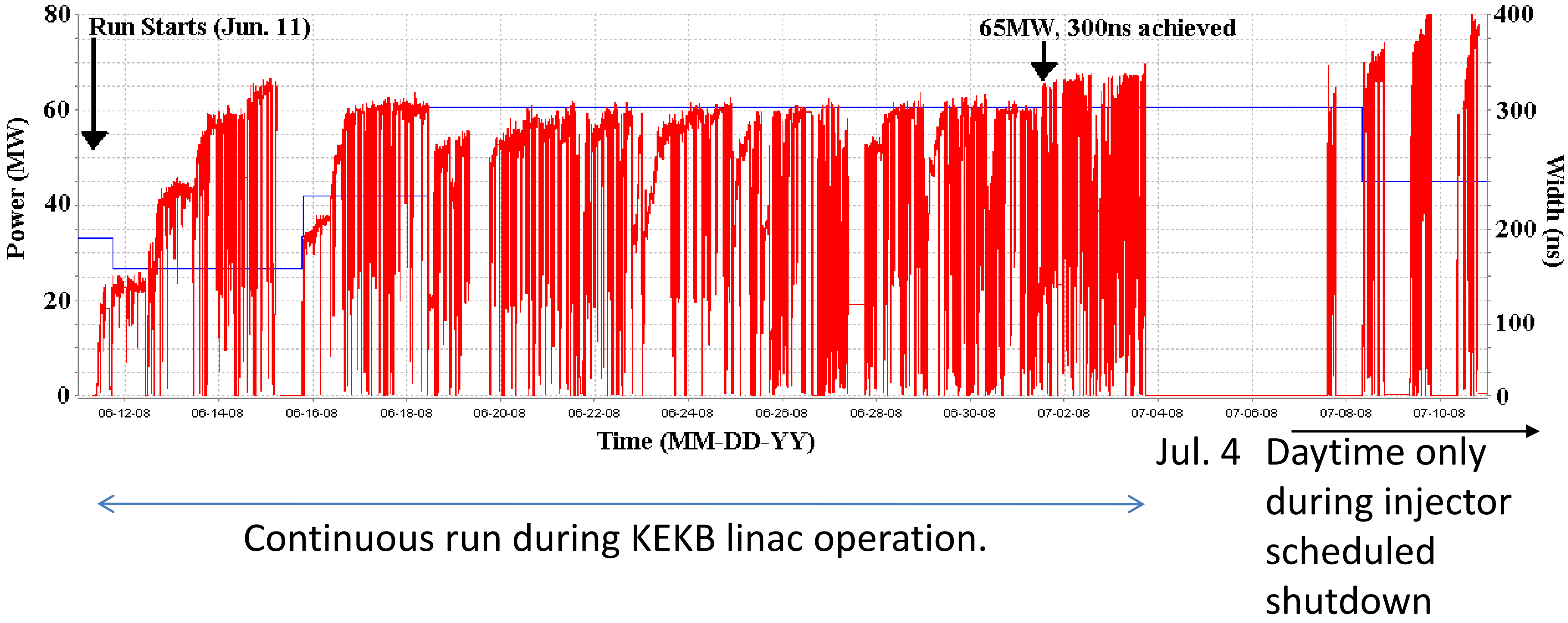


A: Modulator B: Klystrons C: Circular Waveguide D: Accelerator Structure in the Bunker. The control hut is not shown explicitly in the figure.

Frequency	11.424GHz
Max power production	100MW
Max power for test*	75MW
Pulse width	400ns
Repetition rate	50pps

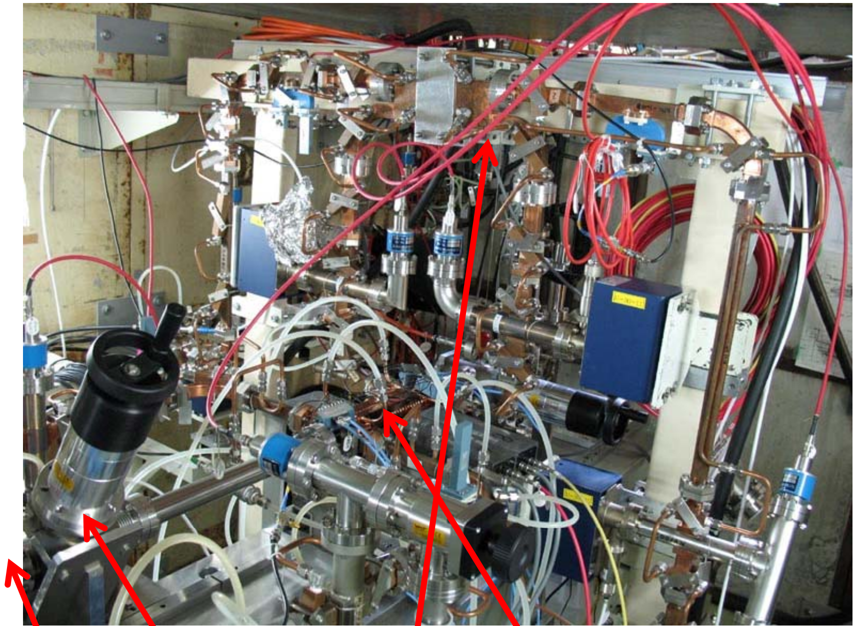
* 25% power loss in the waveguide.

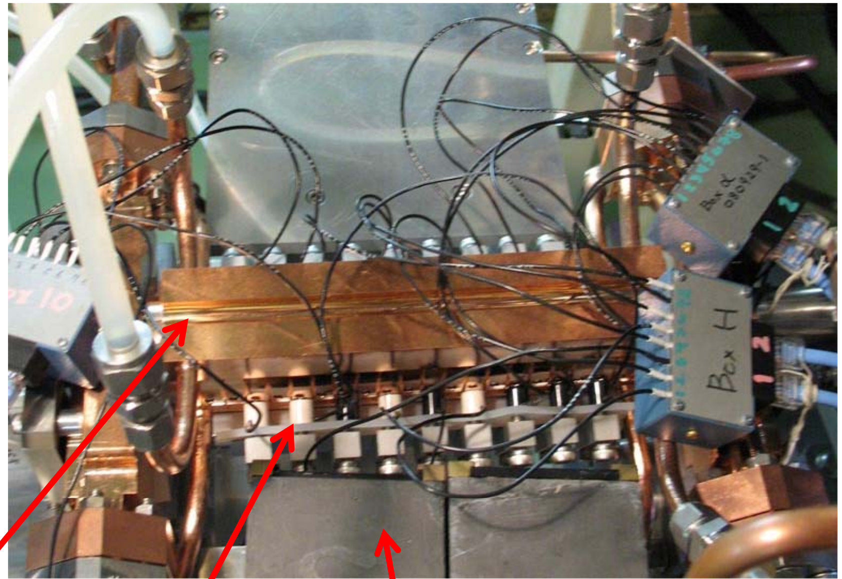
Nextef initial startup with our old structure KX03 in June 2008



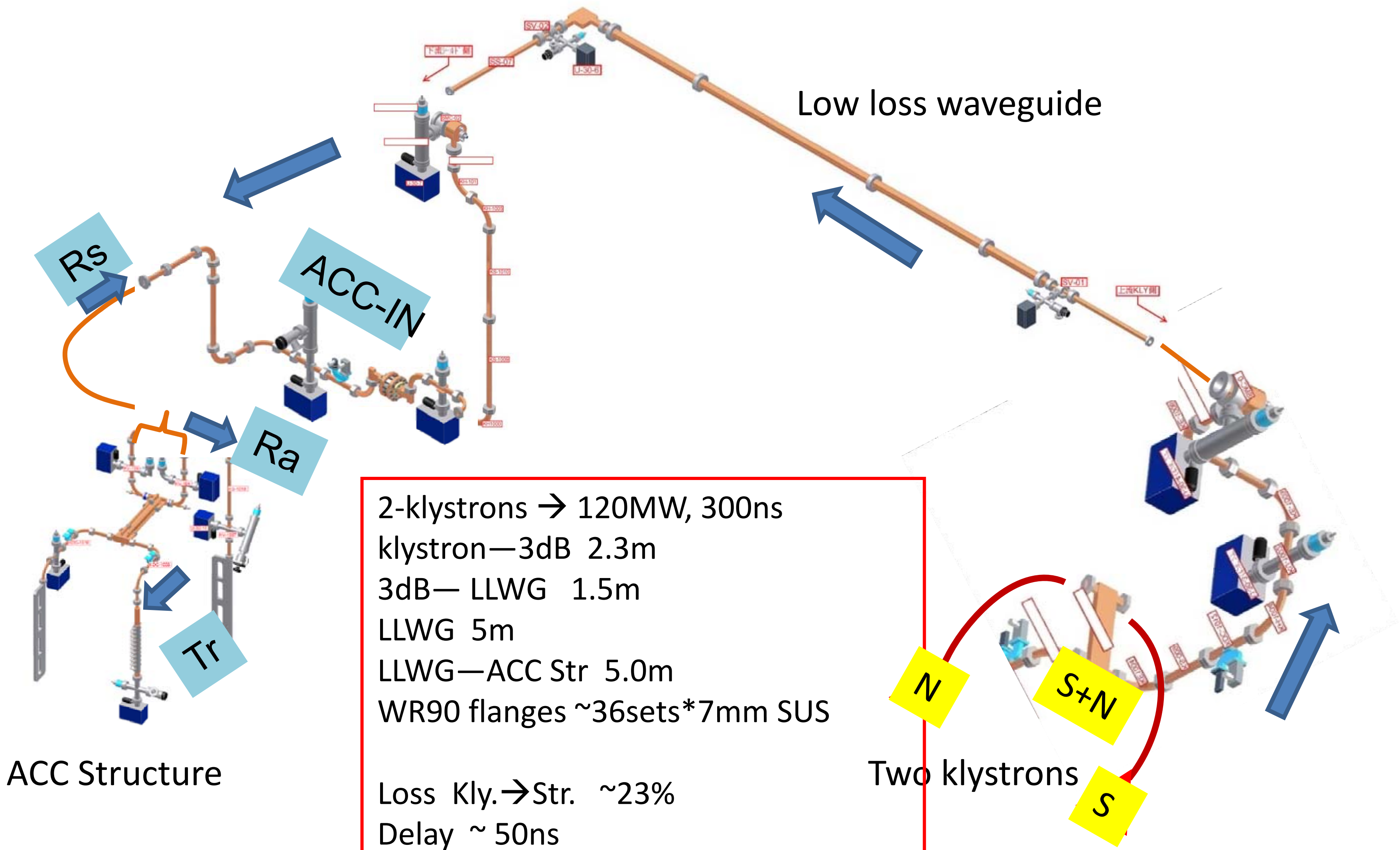
One-month history plots of the RF input power to KX03 (red line) and pulse width (blue) starting from Jun. 11 2008 with KX03 structure installed.

Now T18_VG2.4_Disk #2 has been processed since late September





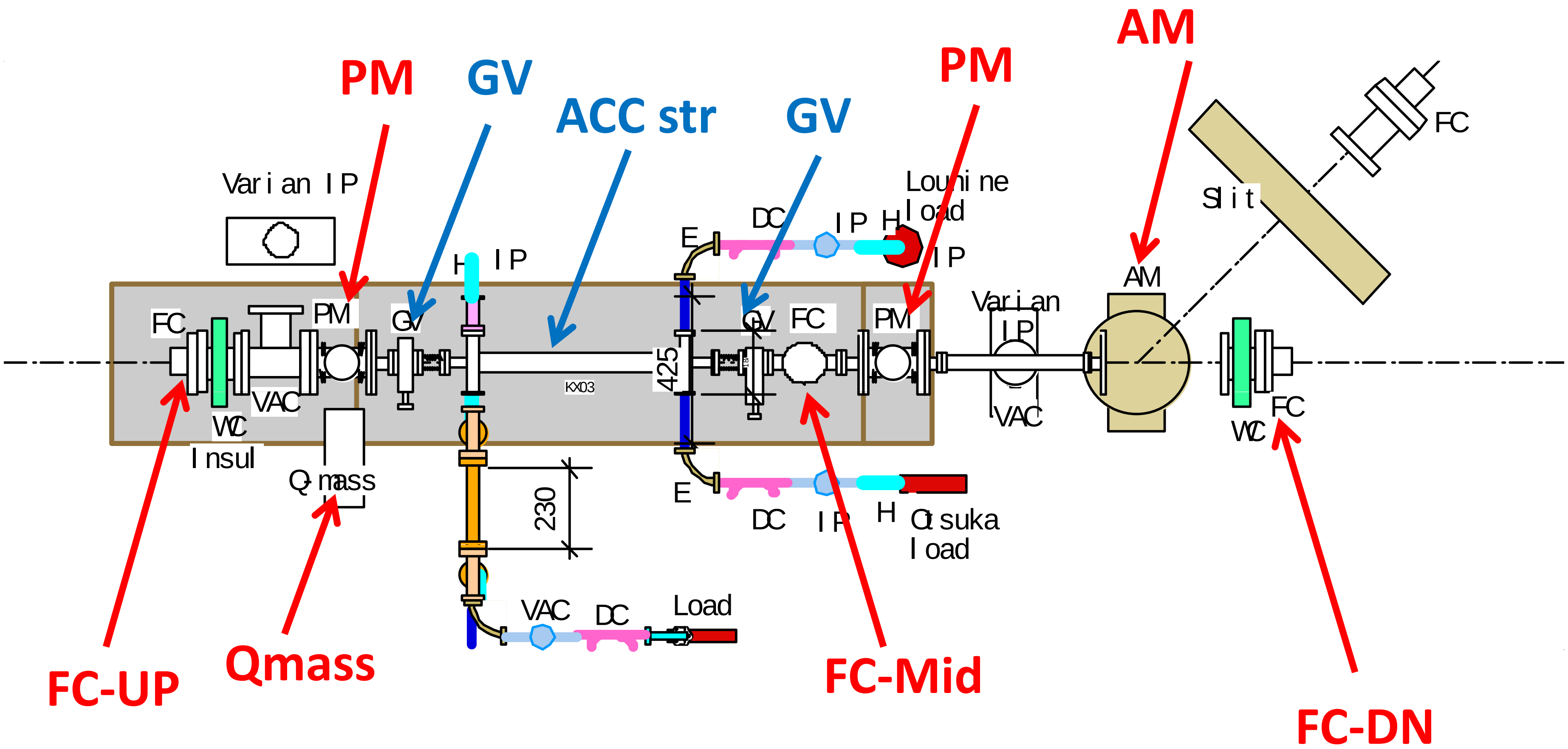
Nextef: RF monitors along waveguide



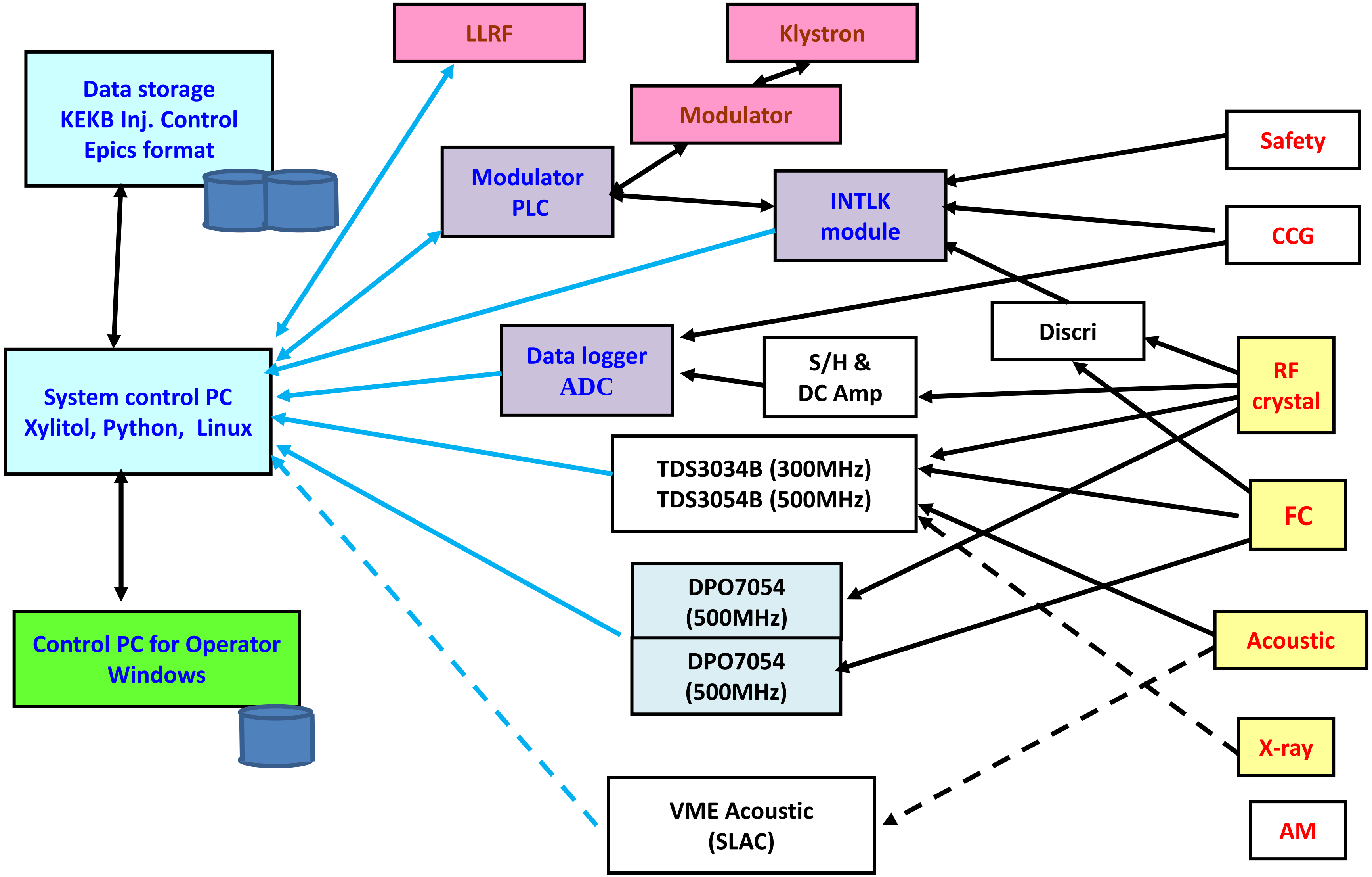
2-klystrons → 120MW, 300ns
klystron—3dB 2.3m
3dB— LLWG 1.5m
LLWG 5m
LLWG—ACC Str 5.0m
WR90 flanges ~36sets*7mm SUS

Loss Kly.→Str. ~23%
Delay ~ 50ns

Nextef: Monitors along beam axis



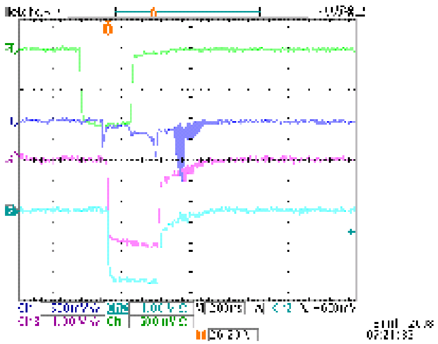
Nextef: Data acquisition flow



Example of observed waveform with KX03

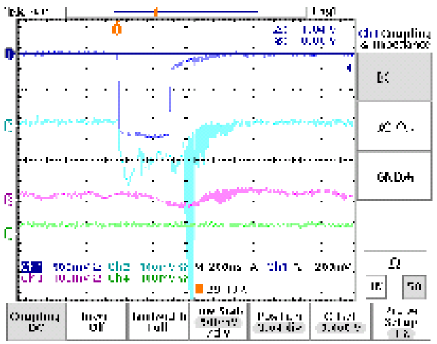
BD at KX03

Event 07:21:25 July 3, 2008



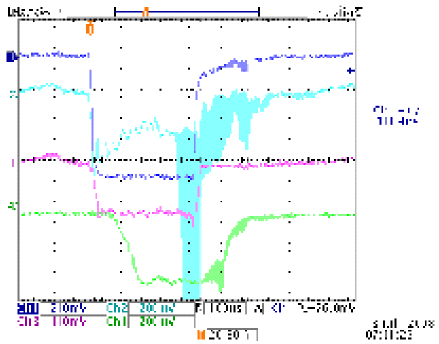
Klystron Output

Ch1: S+N_Load
Ch2: KLY
Ch3: KLY
Ch4: TWT



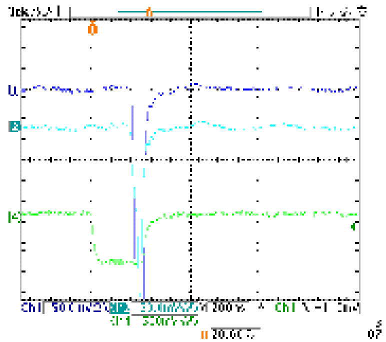
Power combination

Ch1: S+N_Comb
Ch2: S+N_refl
Ch3: GW=light
Ch4:



Accelerator Structure

Ch1: F (ACC_IN)
Ch2: Rs
Ch3: Ra
Ch4: T

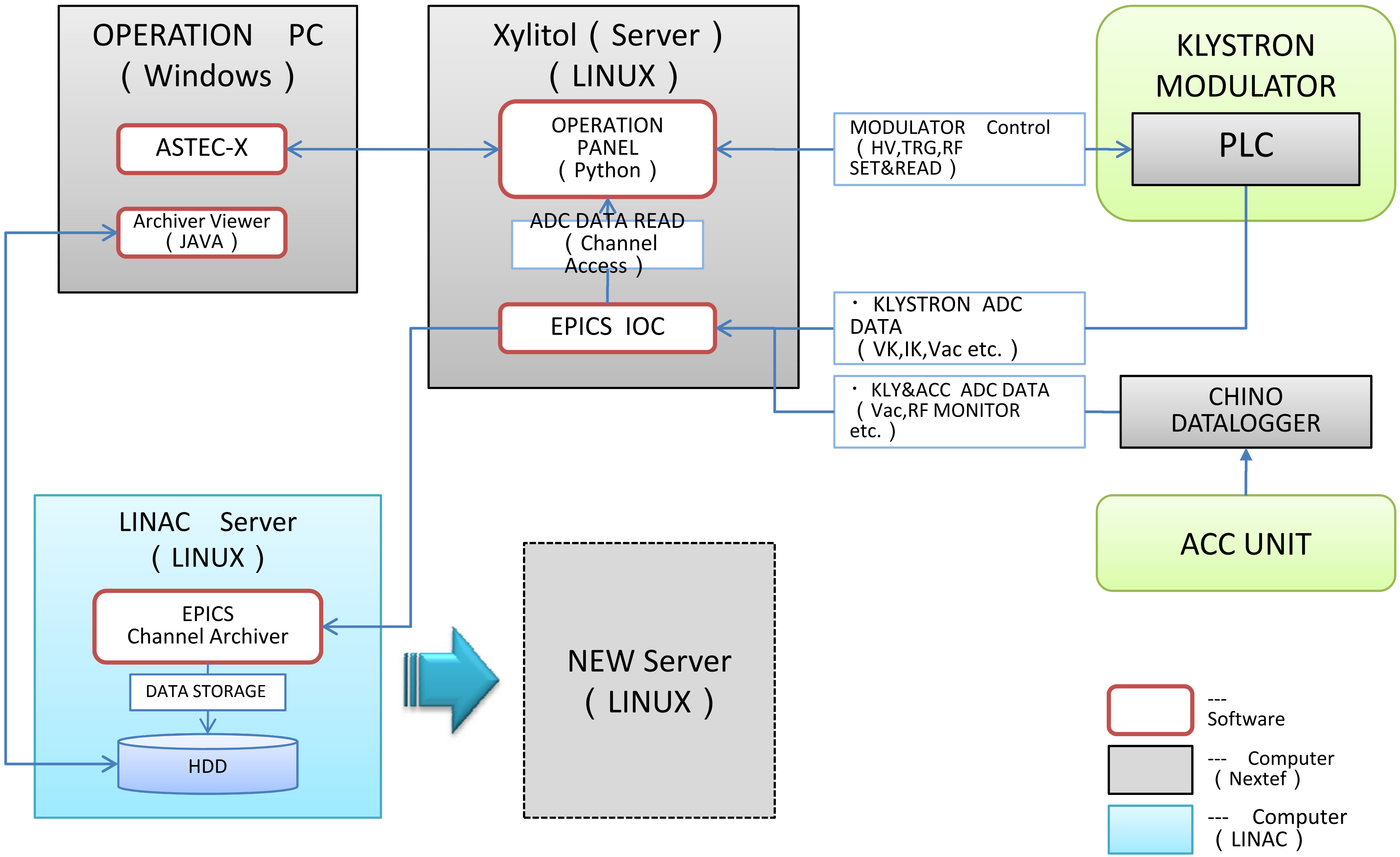


Faraday cups

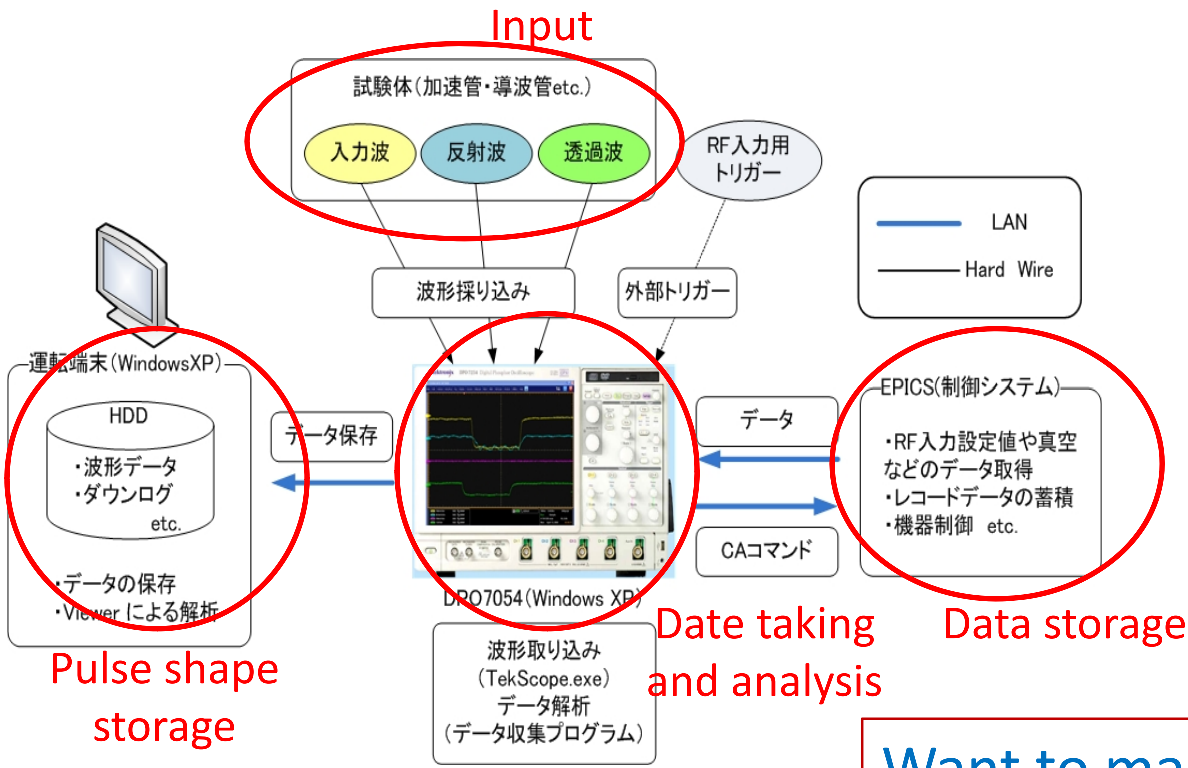
Ch1: FC_UP
Ch2: FC_DN
Ch3:
Ch4: ACC_IN

S. Ushimoto

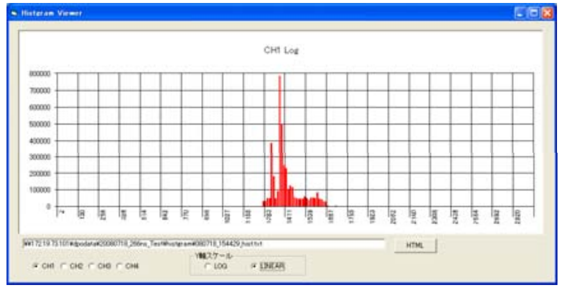
Nextef: Control System（2008）



DPO oscillscope being developed to become a master



DPO system



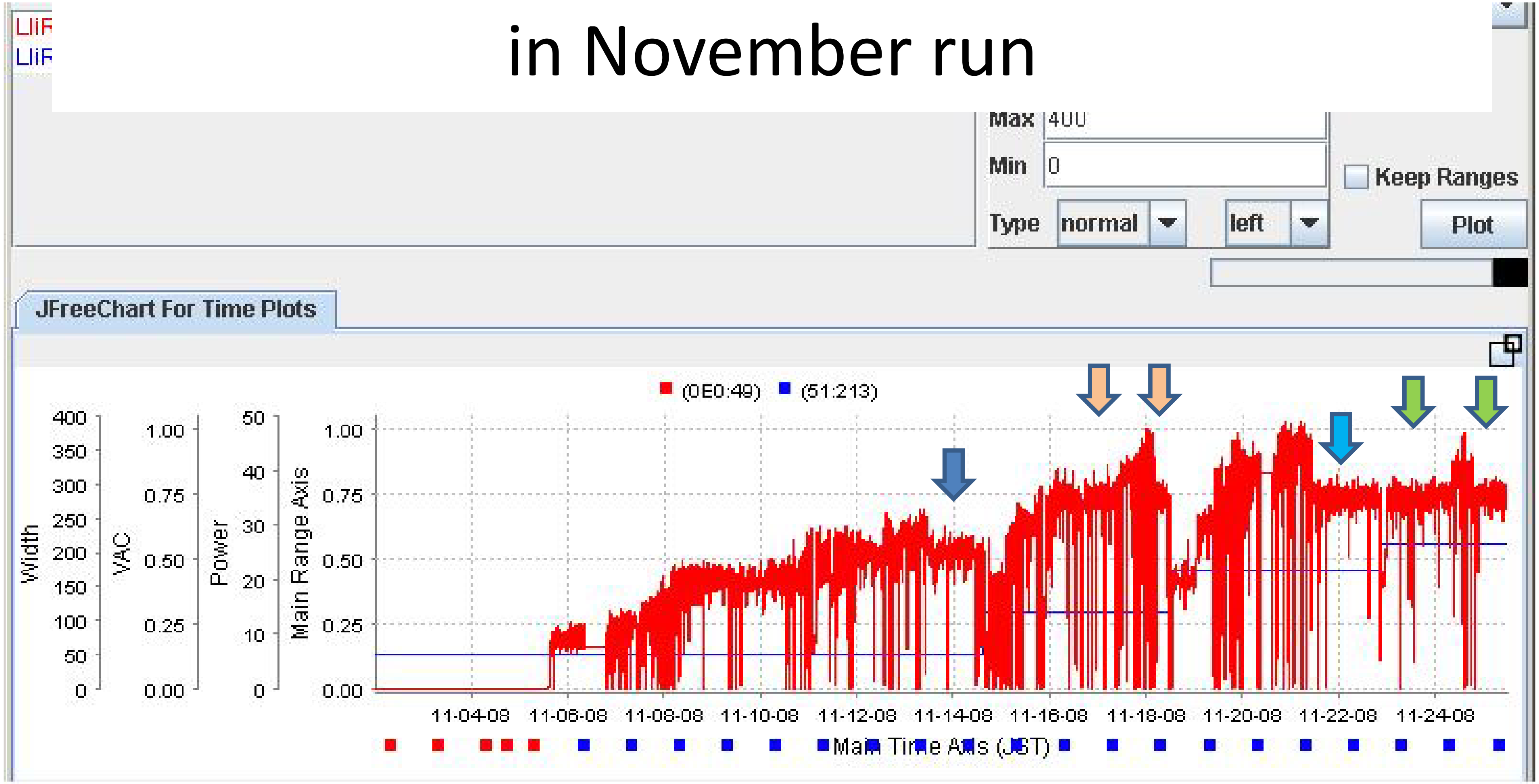
Histogram
We want to implement the on-line statistical views.

Want to make this system to be our nominal power reference

Breakdown related monitors and their recording

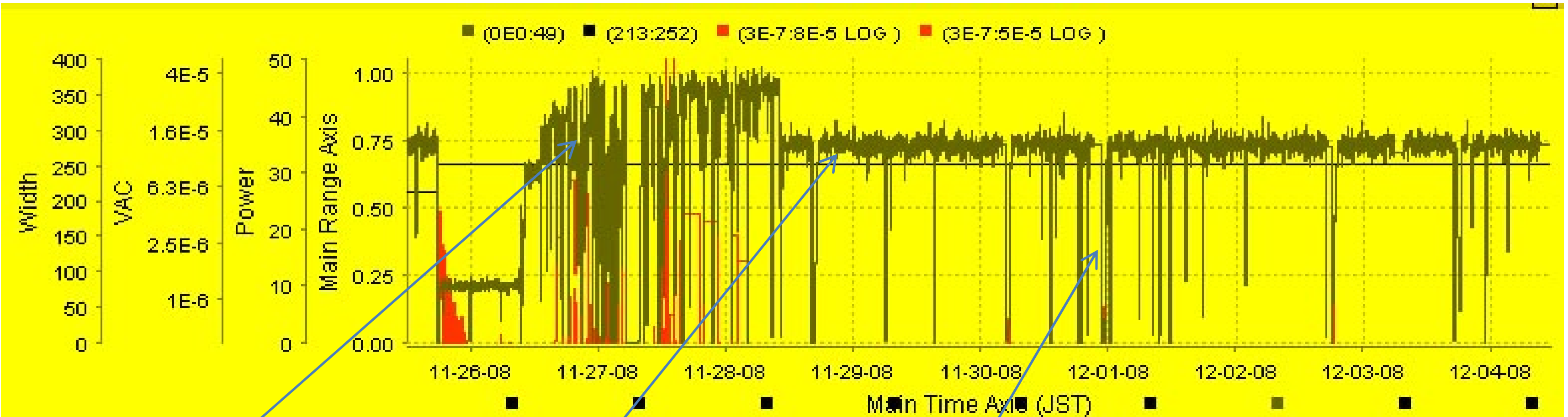
- DPO7054: F, Rs, Ra, T, FC-UP, FC-Mid → 8 values
  - Recording 10 pulses with BD pulse at the last
  - This gives feed power level just before BD
  - Use this intensively for breakdown pulse analysis
  - Nominal pulses are to be routinely recorded (not yet implemented)
    - With and without RF, take automatically
- TDS3000: Mod, S, N, S+N, S+N_refl, acoustic, X-ray, ...
  - Recording for each BD and every one hour
  - Recording last pulse and/or a few pulse shapes in png and wfm
  - These make it possible to distinguish the breakdown whether ACC origin or due to other components

Actual processing with T18_VG2.4_Disk #2 in November run



Data taken at 80MV/m.

Recent 253ns processing and 80MV/m run with power from crystal-P/H-ADC appeared in control program panel

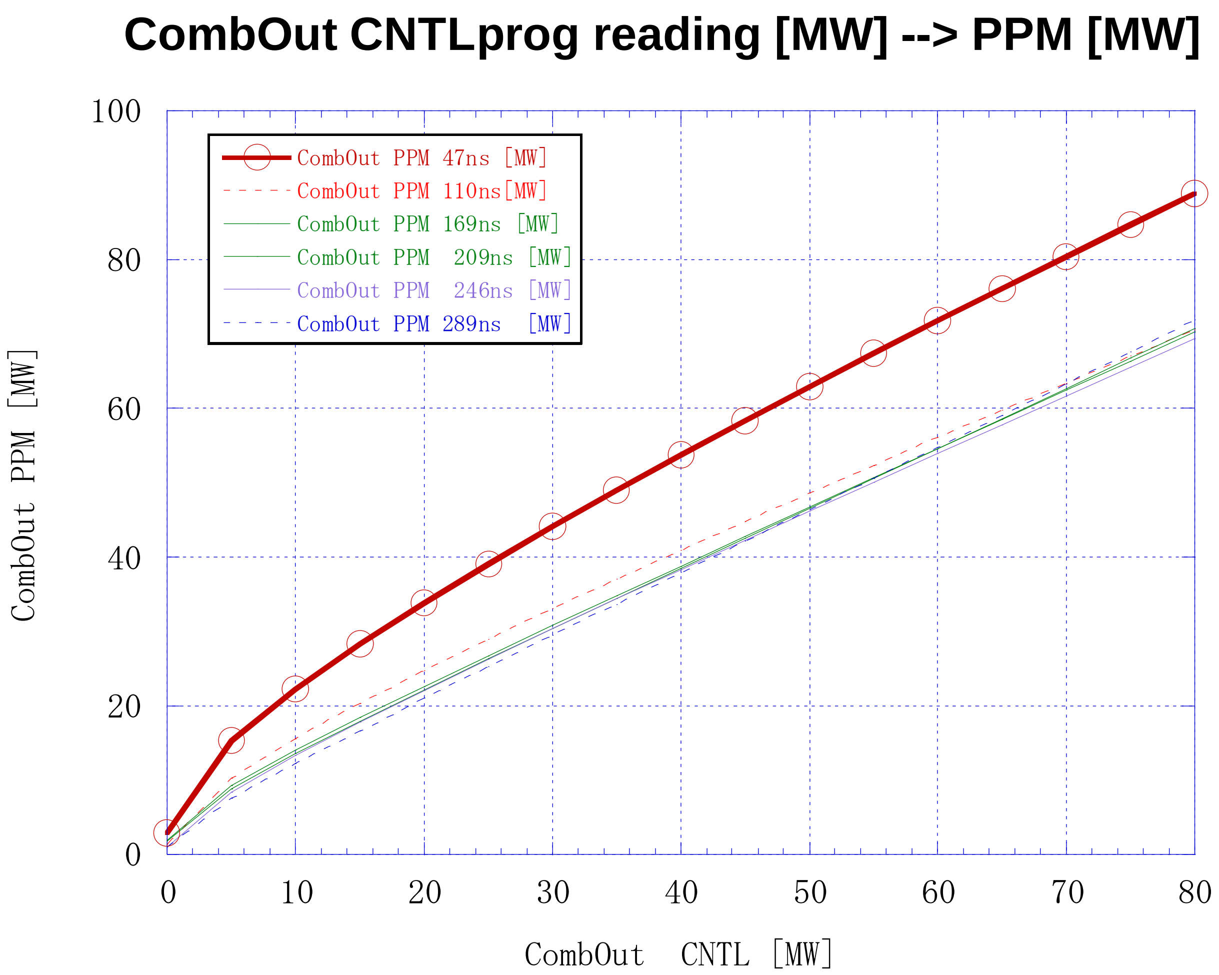


Processing to 90MV/m.

Stable run at 80MV/m.

Most of the trips are due to klystron related matter.
We are off-line analysed.

Power calibration
Actual vs control program monitor



CNTL program read crystal → PH → DC AMP → ADC

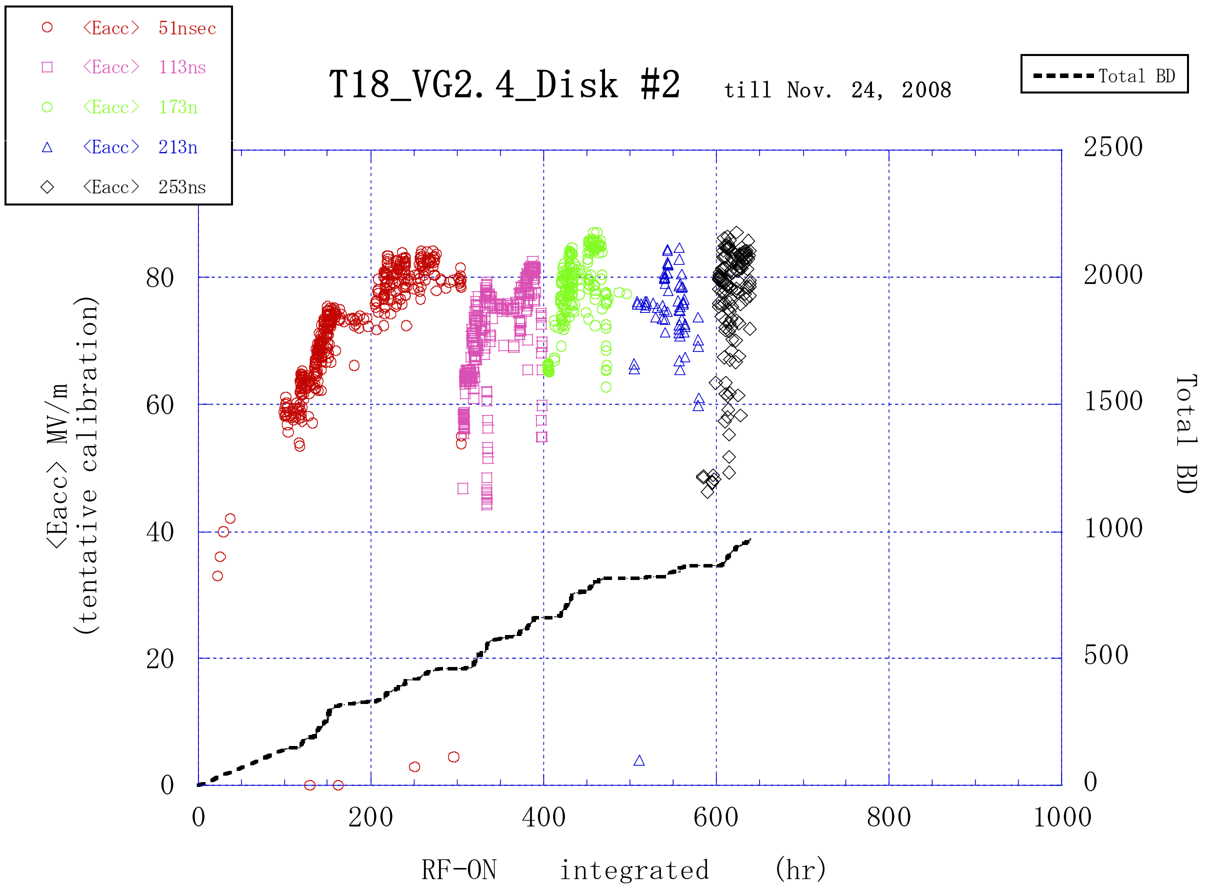
Calibrated with peak power meter as nominal value

Some insufficient calibration still exists on pulse width

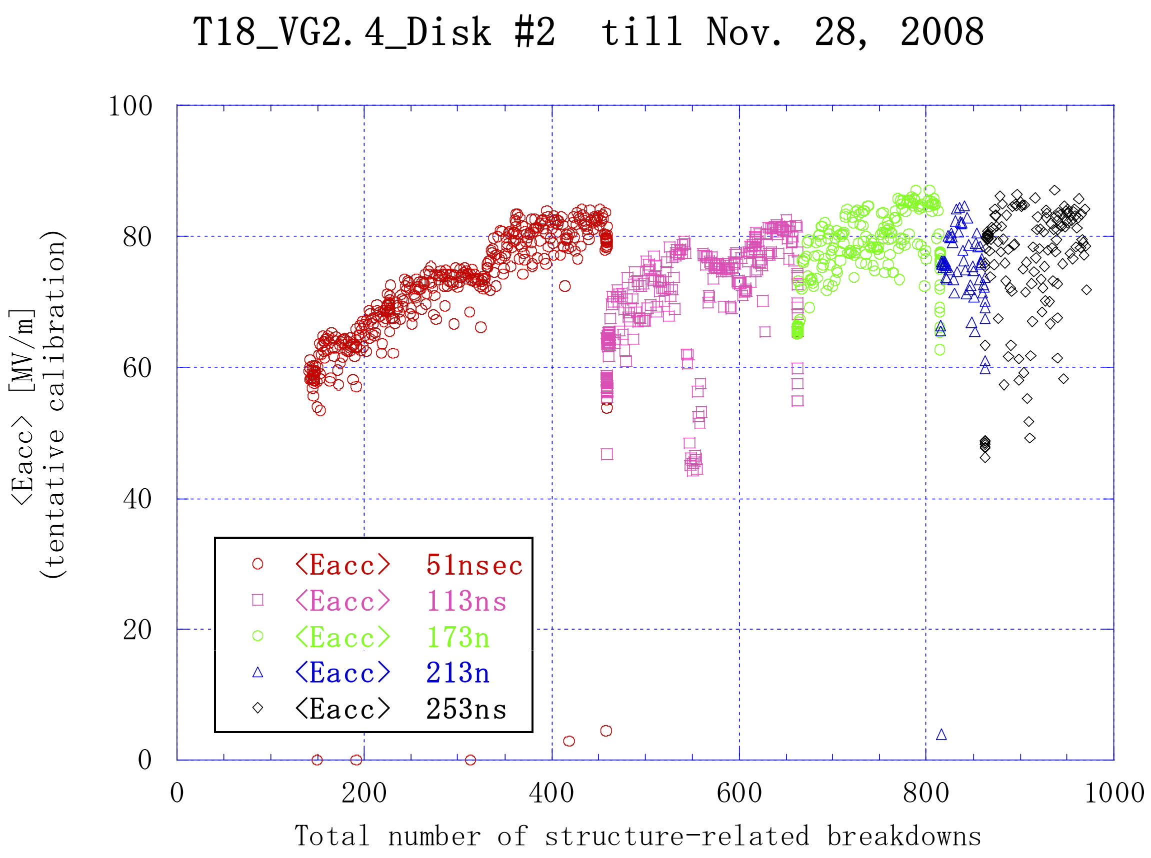
Checked with calorimetric method for output from structure

DPO power reading versus RF-ON hours

DPO reads directly crystal output through an amplifier.
Trips are made in case of jump in FC, Rs, etc.



DPO power reading versus total number of breakdowns



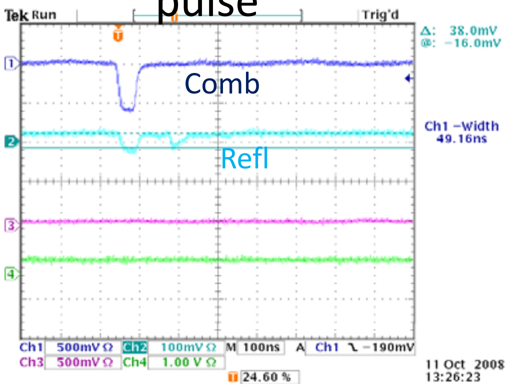
Typical pulse shape

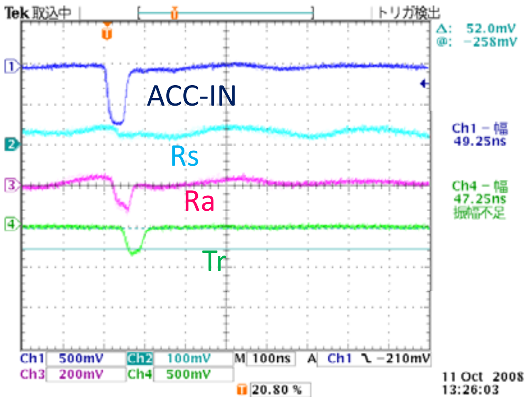
Nominal pulse

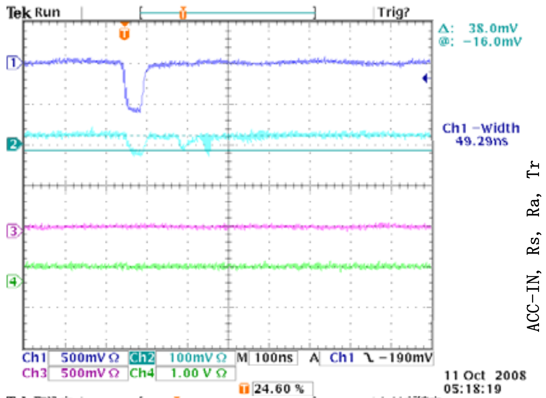
TDS3000

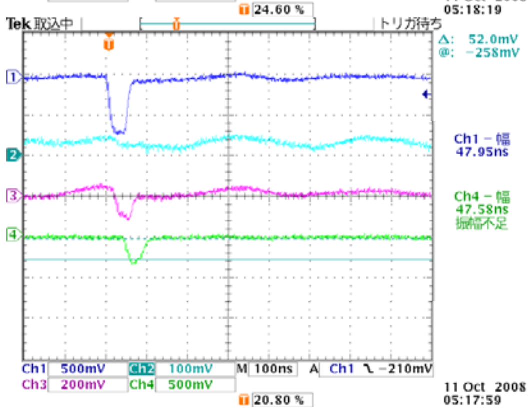
BD pulse

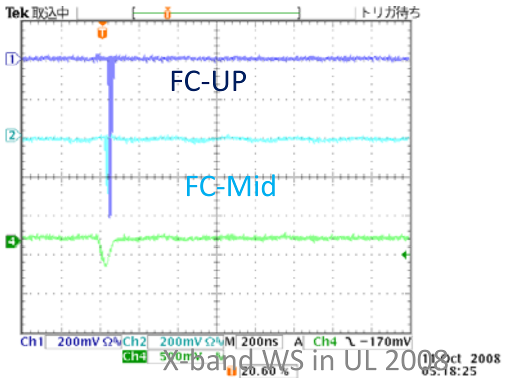
DPO7054



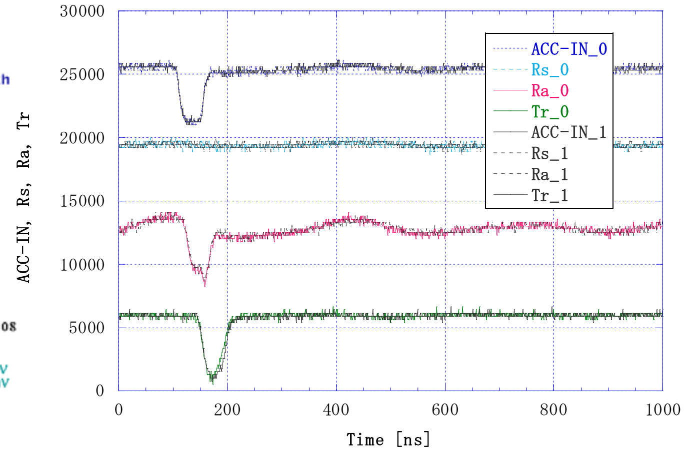




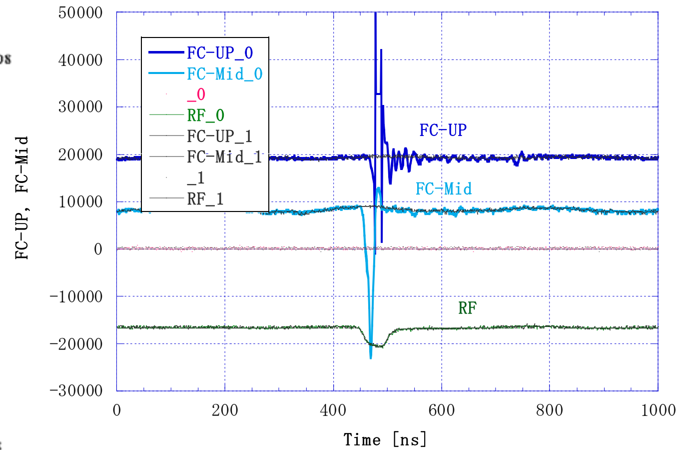




RF pulse



FC current pulse at BD



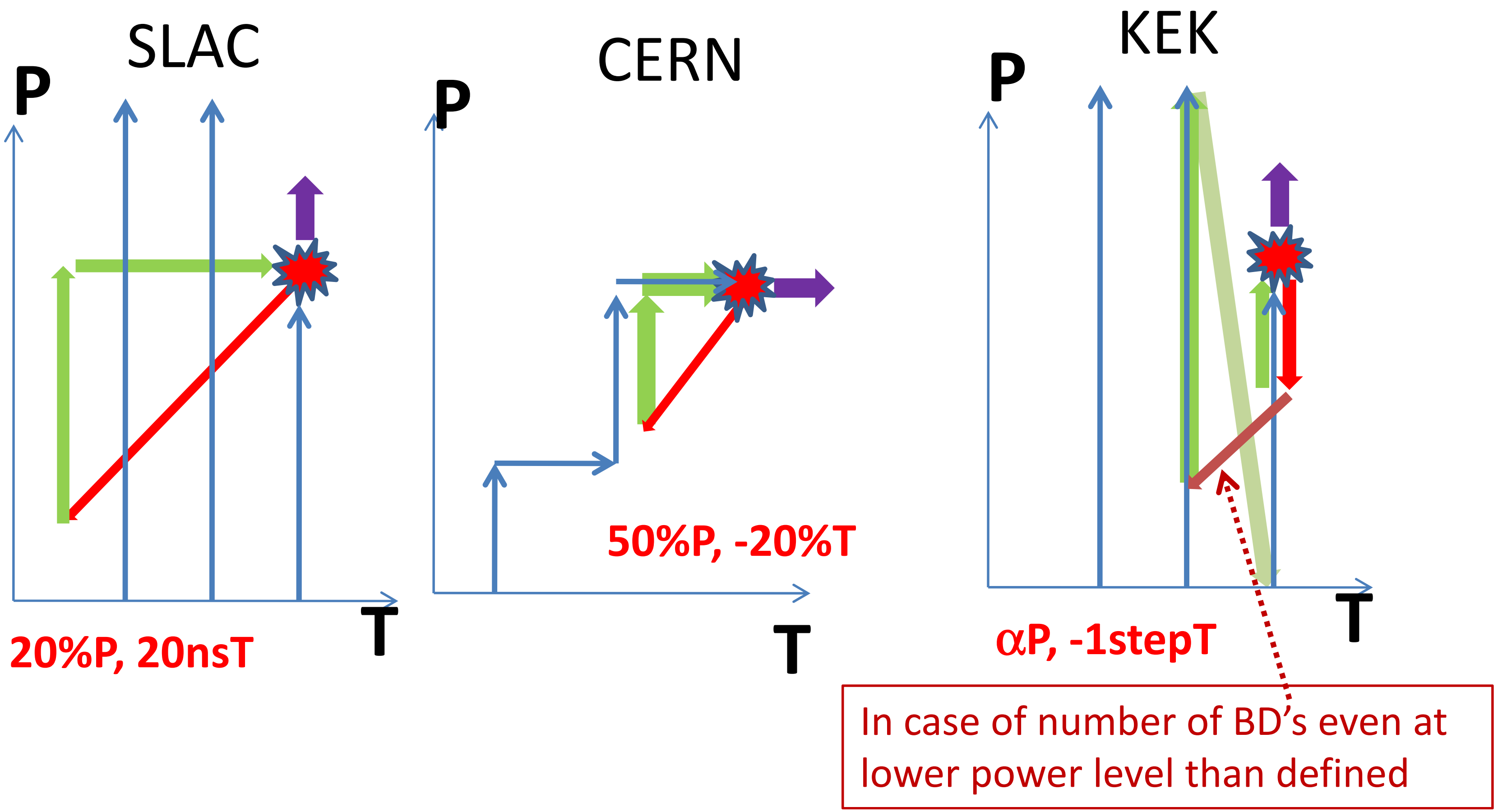
Still to be developed

- Processing control
  - Sophistication will be done through T18_VG2.4_Disk processing period
  - Processing protocol should be improved
- Data acquisition system
  - Establish DPO to be nominal input power reference
  - Data storage should be established with backup area
- Data analysis
  - Online viewing and monitoring program is needed
  - Consistent analysis through longer period is needed
- Need support from outside
  - Want to expect outside manpower and experience
  - And improve the analysis with better judgment and recording

Processing control for T18_VG2.4_Disk #2

- Step-wise pulse width setting
  - 50-110-170-210-250- followed by-290ns
- ACC-originated INTLK
  - Rs: Threshold setting is now manually done , a little above nominal
  - FC: upstream and downstream, threshold set at 100mV in 50Ω
  - VAC level nominal 10^{-4}Pa
- Arcing in waveguide system
  - S+N_refl (reflection to the combiner of two klystrons) and VAC
- Recovery from breakdown
  - Nominal recovery is automatically done by power reduction and gradual increase.
  - In case of breakdowns at considerably lower power level than the previously reached level, say below 50%, automatically decrease pulse width by one step.

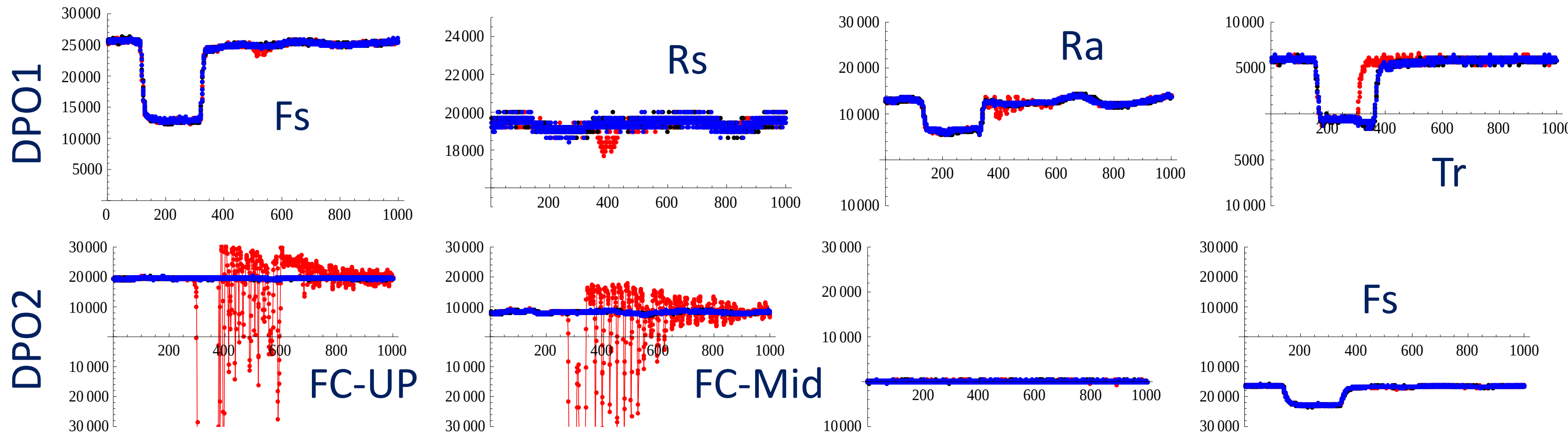
Recovery pass in (T,P) space



Big breakdown followed by a breakdown from the very first pulse

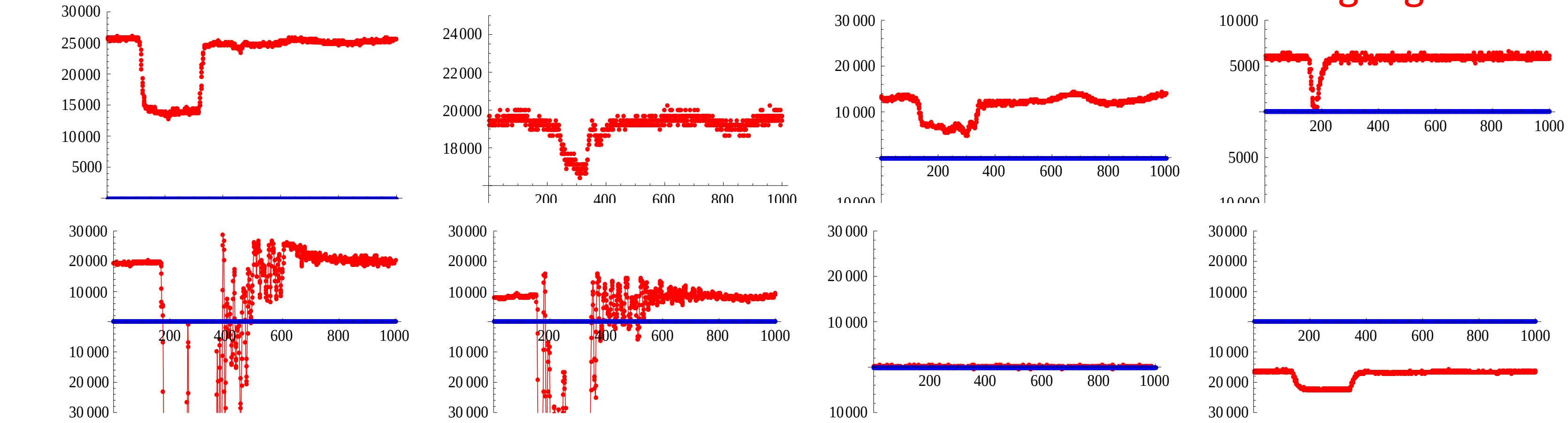
file number= 3 20081124_210211_1 Red=final, black=previous pulse and blue=-2nd pulse

Nominal BD



file number= 4 20081124_210301_1 Red=final, black=previous pulse and blue=-2nd pulse

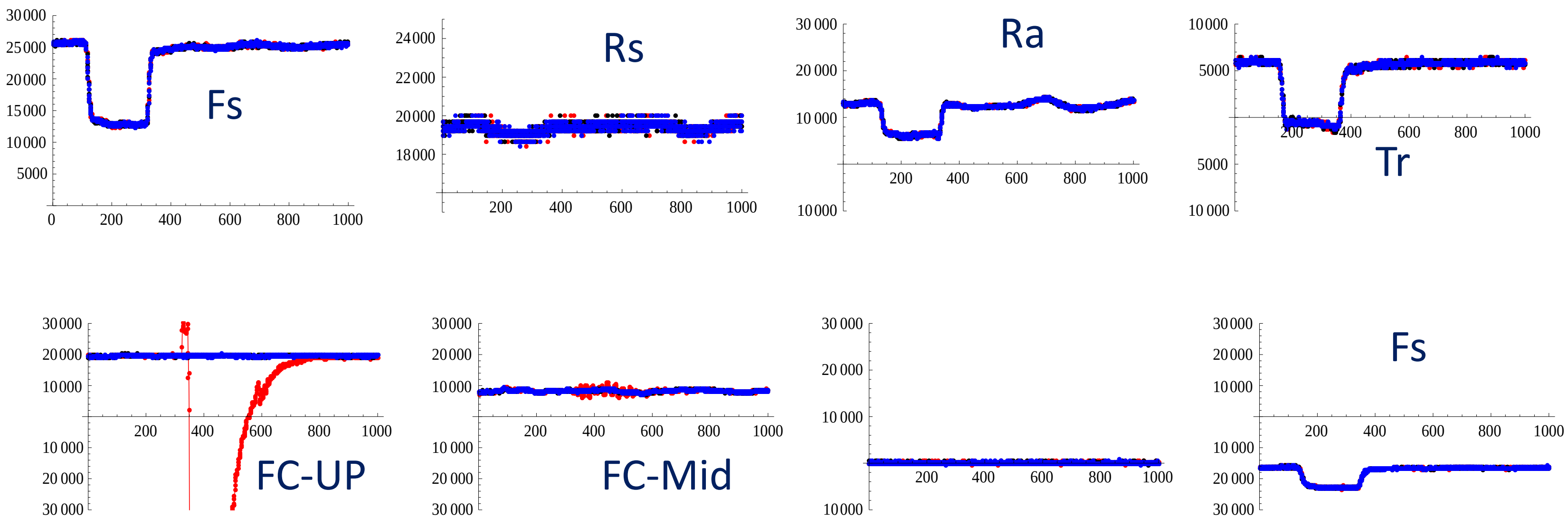
1^{st} pulse BD, following big BD



Modify processing protocol?

- We suffer from the breakdown from the very first pulse
  - Even with a little reduced power level
- Worthwhile to modify the protocol with taking the same action as CERN-SLAC protocol
  - After BD, always decrease pulse width
  - This is under consideration, but may not be implemented till the next processing

Current burst toward upstream



Rare event but need to understand the mechanism

One out of 100 breakdowns

Abrupt big burst in current only to upstream

no change in RF pulse shape

How and what to compare in high gradient evaluations by different systems

- How to compare different high gradient experiments
  - Exchange the structures?
  - Power cross checking now 10% level → % level
  - Processing protocol processing speed, recovery manner
  - Breakdown criteria missing energy / reflection amplitude / complex reflection vector
- What to compare
  - BDR at some field levels is needed
    - very high gradient ~150MV/m
    - medium ~>100MV/m
    - practical ~80MV/m
  - Performance until reaching the final status
  - Performance in long-term running
  - Other observables than BDR?
    - Field enhancement factor, dark current …..

Issues for understanding the performance

- We need to discuss the way to consistently compare and understand
- Various levels
  - Field: 80 – 100 – 150 MV/m
  - Pulse shape: Pulse length, pulse shape, ……
- Relationship
  - Pulse heating vs BDR
  - DC Pulse / Waveguide / single cell / pulse heating

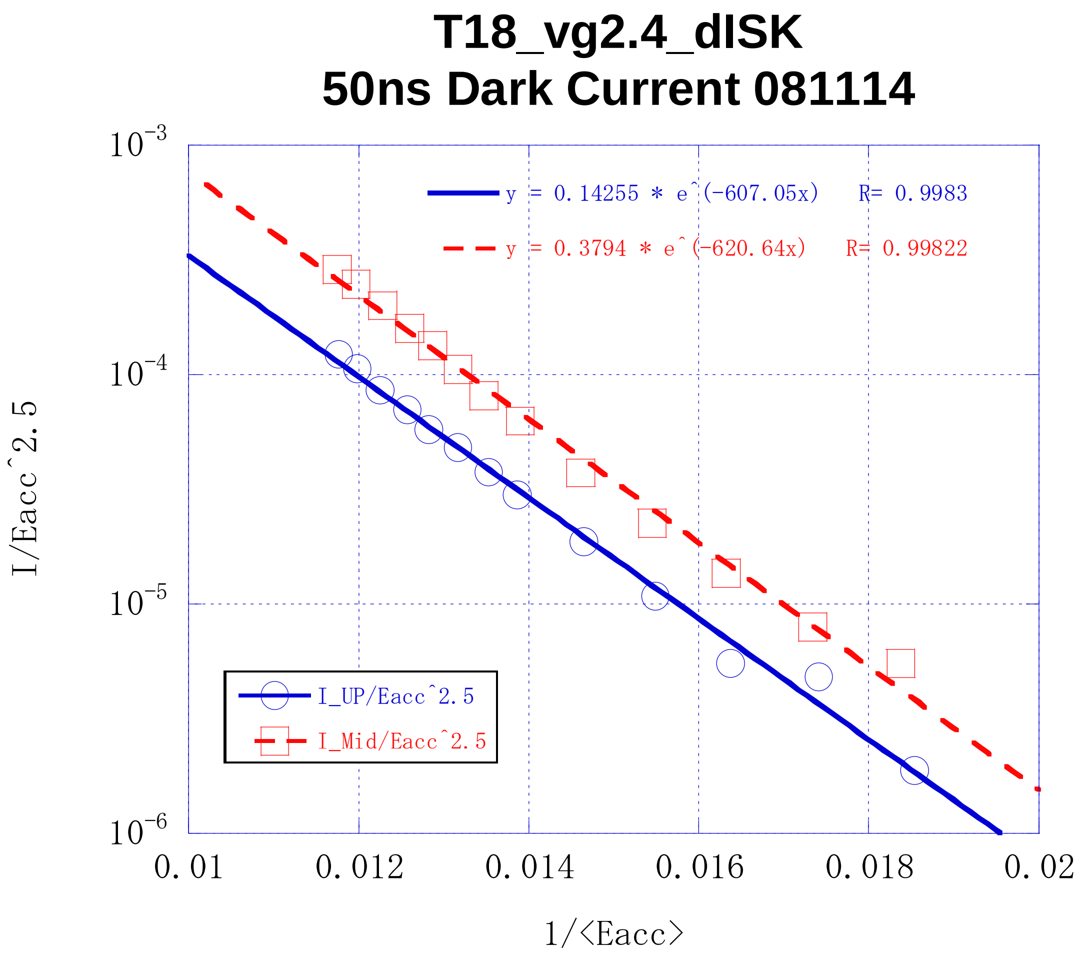
Breakdown rate

- Measured after reaching 90MV/m and stay at 80MV/m
- Measurement (to be analysed)
  - At 53ns; 2 BD's in 26.5 hours
  - At 113ns; 102 BD's in 61 hours
  - 0 BD in 5.5 hours
  - At 173ns; 1 BD in 11 hours
  - At 213ns; 7 BD's in 31 hours
  - 6 BD's in 17 hours (all BD in initial 2 hours)
  - At 253ns; to be done from time to time in a month

Stable dark current

- DC current measurement down to pA level
  - Peak current of 10 μA level
  - Sometimes fluctuates but the amount of fluctuation is not yet evaluated.
  - RF pulse change is not observed associated with the fluctuation.
- Modified FN formula is applied
  - In the dependence with gradient
- Energy spectrum
  - To be done

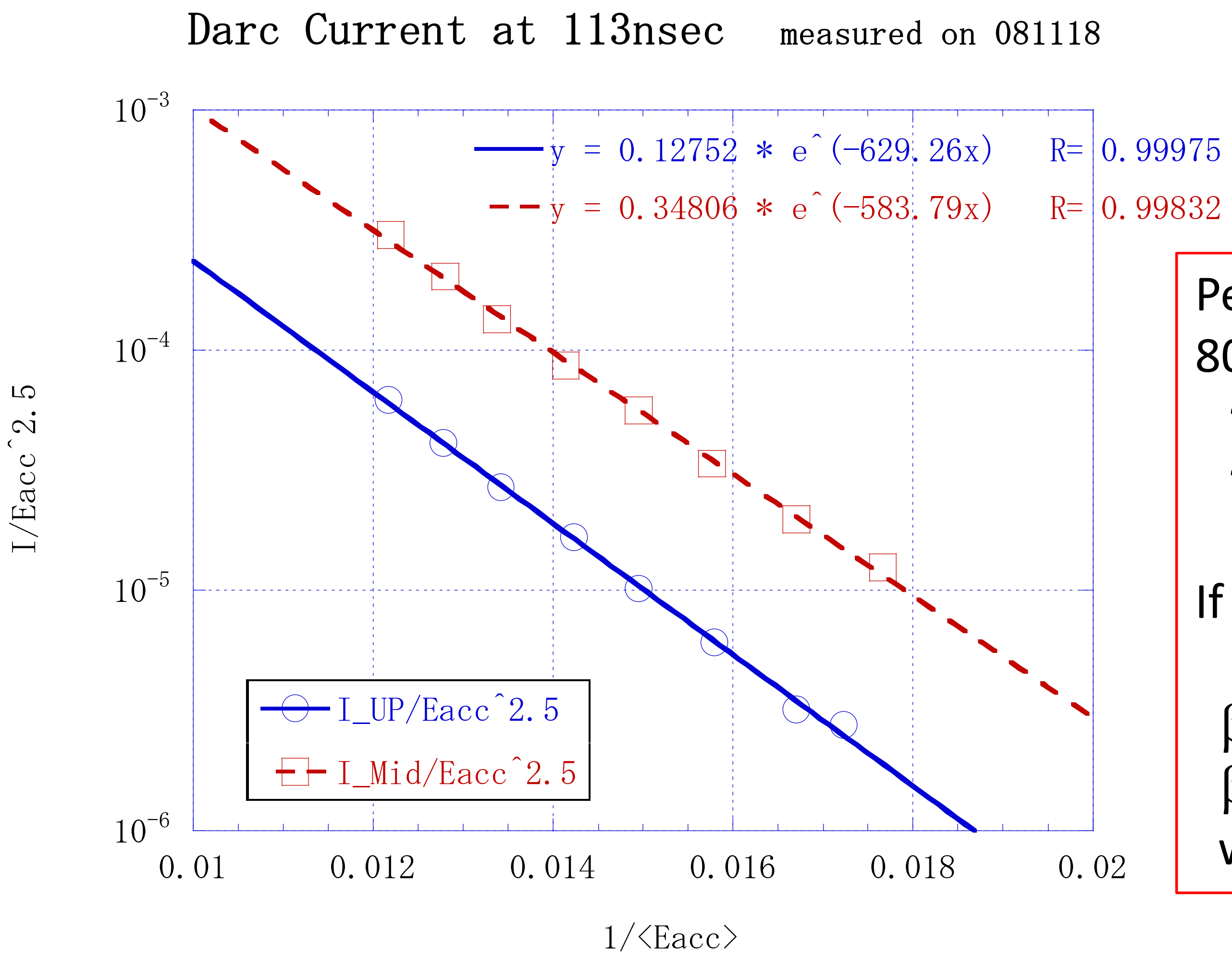
Dark current at 80MV/m, 50ns 081114



Peak current at 80MV/m
- ~8μA to UP
- ~19μA to Mid

If assume Es=2 Eacc then
- β UP =60
- β Mid =59
- with ϕ=5eV

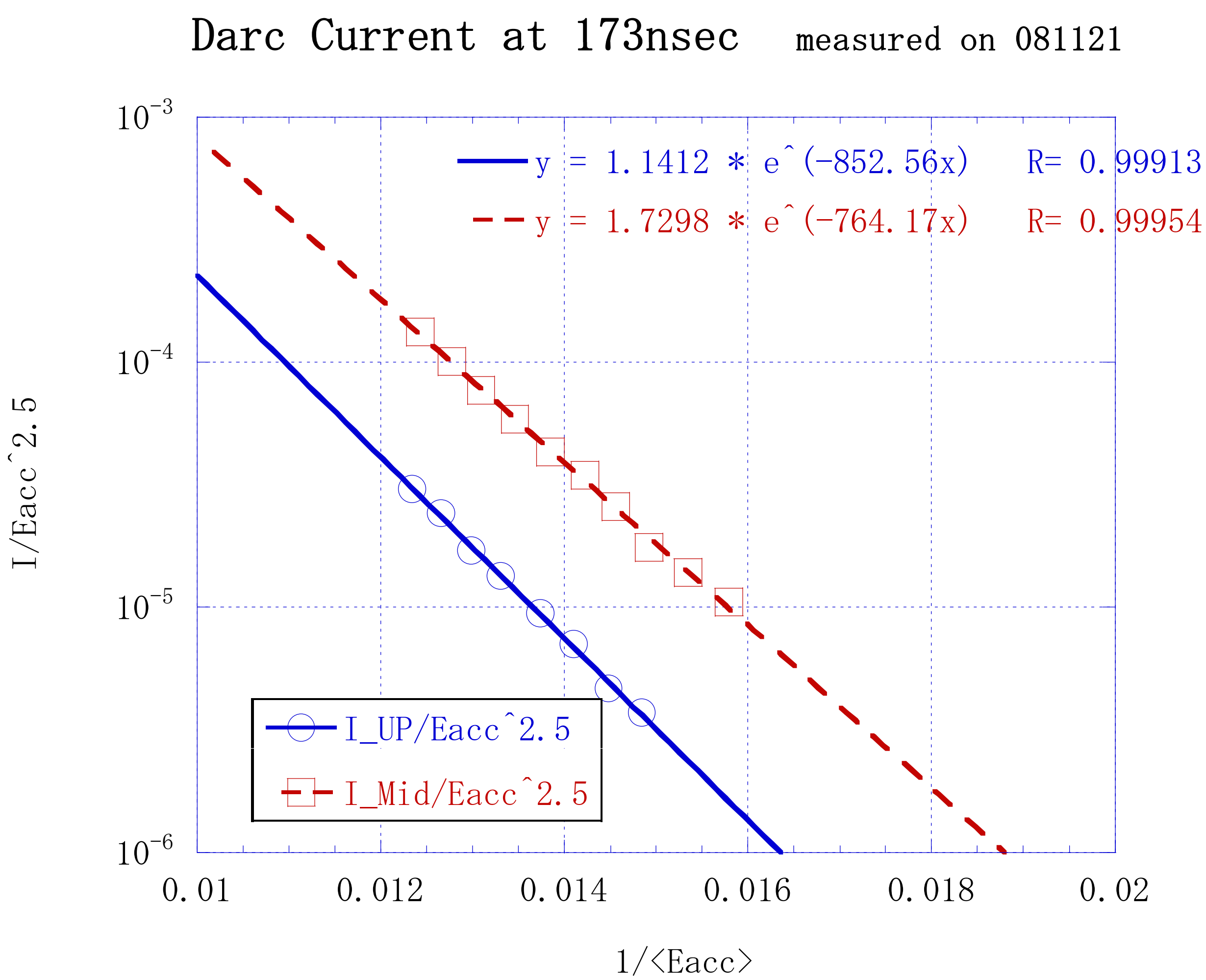
Dark current at 80MV/m, 113ns 081118



Peak current at 80MV/m
~7μA to UP
~33μA to Mid

If assume Es=2 Eacc then
β UP =58
β Mid =63
with ϕ=5eV

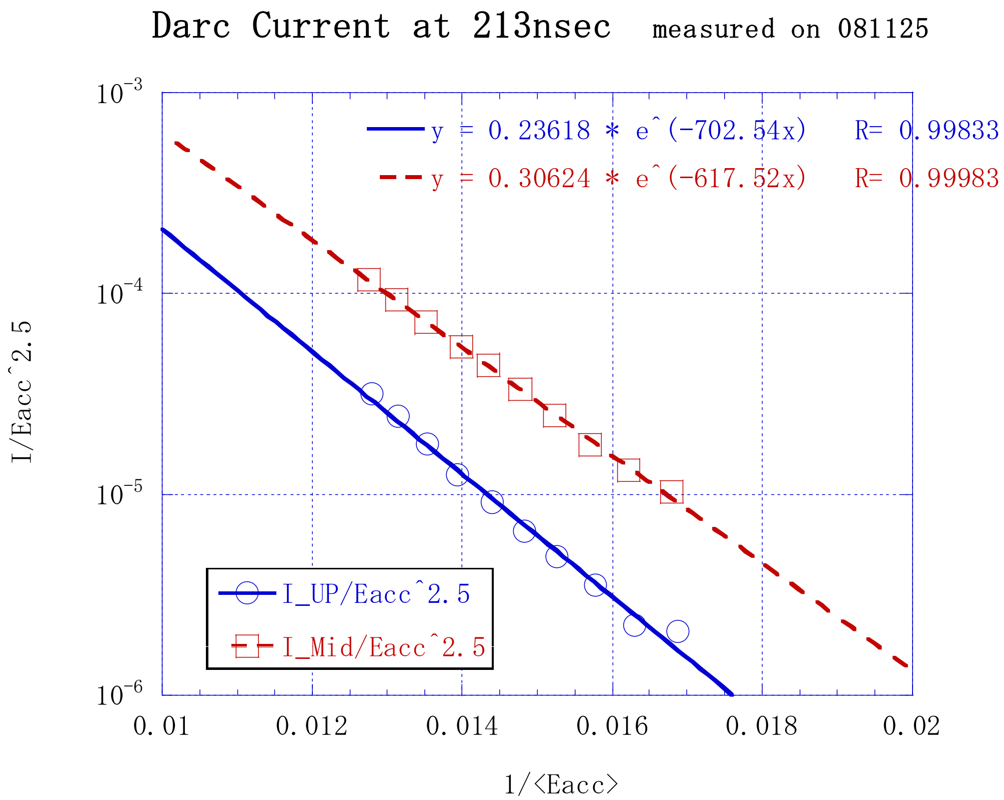
Dark current at 80MV/m, 173ns 081121



Peak current at 80MV/m
~4μA to UP
~20μA to Mid

If assume Es=2 Eacc
then
β UP =43
β Mid =48
with ϕ=5eV

Dark current at 80MV/m, 213ns 0811??



Peak current at 80MV/m
~3μA to UP
~10μA to Mid

If assume Es=2 Eacc then
β UP =49
β Mid =57
with ϕ=5eV

Dark current at 80MV/m, 253ns 081128

Yet to be analysed

Dark current amount and field enhancement factor β

$$\frac{I}{E^{2.5}} \propto e^{-\frac{6.53\times 10^{9}\,\phi^{1.5}}{\beta E}} = e^{-\frac{\alpha}{E(MV/m)}} \quad \Rightarrow \quad \beta = \frac{6530\,\phi^{1.5}}{\alpha}$$

Date	Data #	nsec	FC-UP microA	beta-UP	FC-Mid microA	beta-Mid
081114	1	53	8	60	19	59
081118	2	113	7	58	33	63
081121	3	173	4	43	20	48
081124	4	213	3	49	10	57

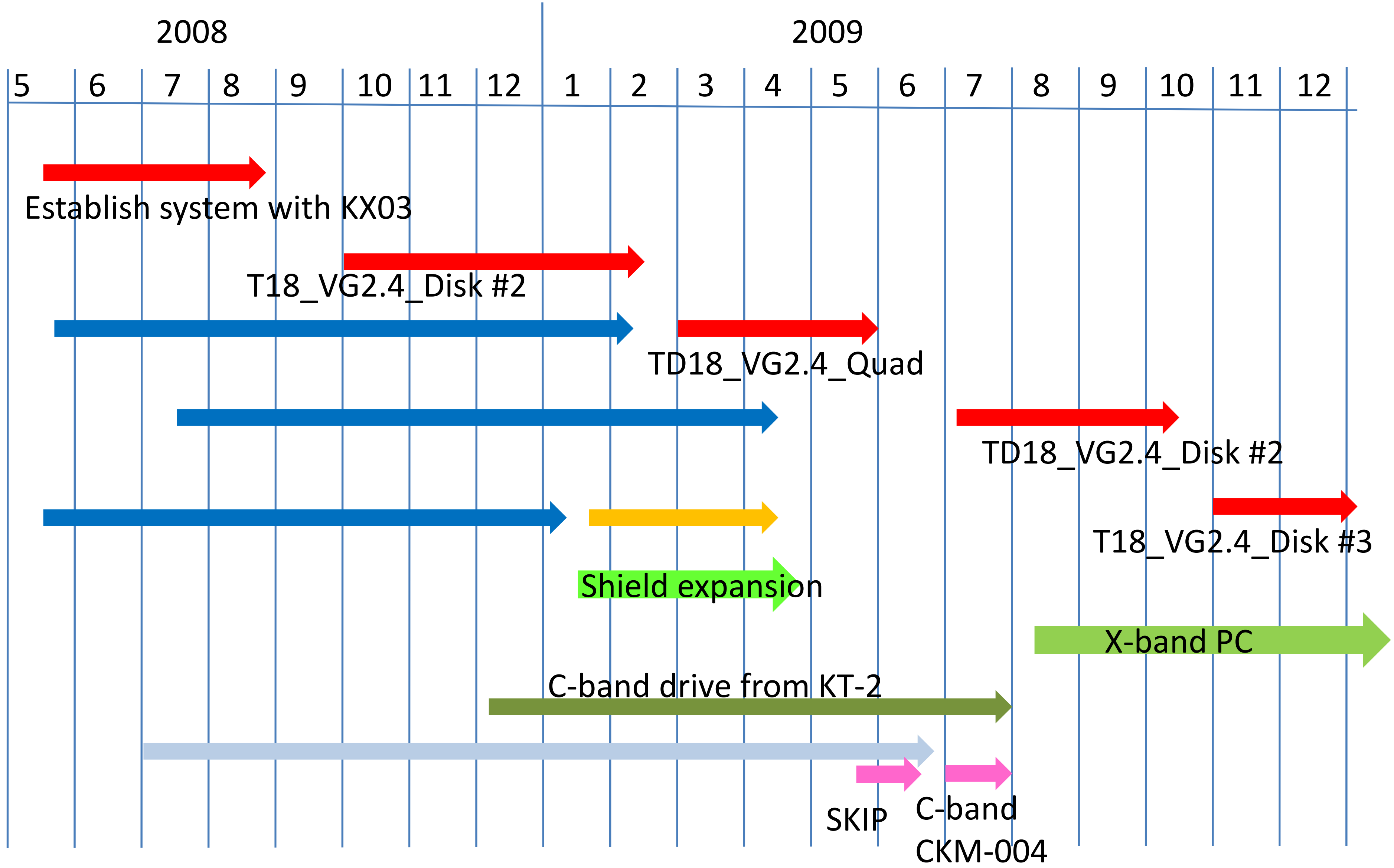
Processing summary till late Nov.

- Processing reached up to 253ns, 90MV/m
  - 1000 BD's in 650 hours
- Breakdown rate
  - <1BD/15hr ~ <2x10^{-6} BD/pulse/m 80MV/m, 213ns just after processing
- Dark current
  - Toward upstream 5~10μA
  - Toward downstream 20 ~30μA
  - Field enhance factor around 40~60
- Our strategy
  - stay at 253ns, 80MVm for a month
  - then restart processing to 100 MV/m and higher

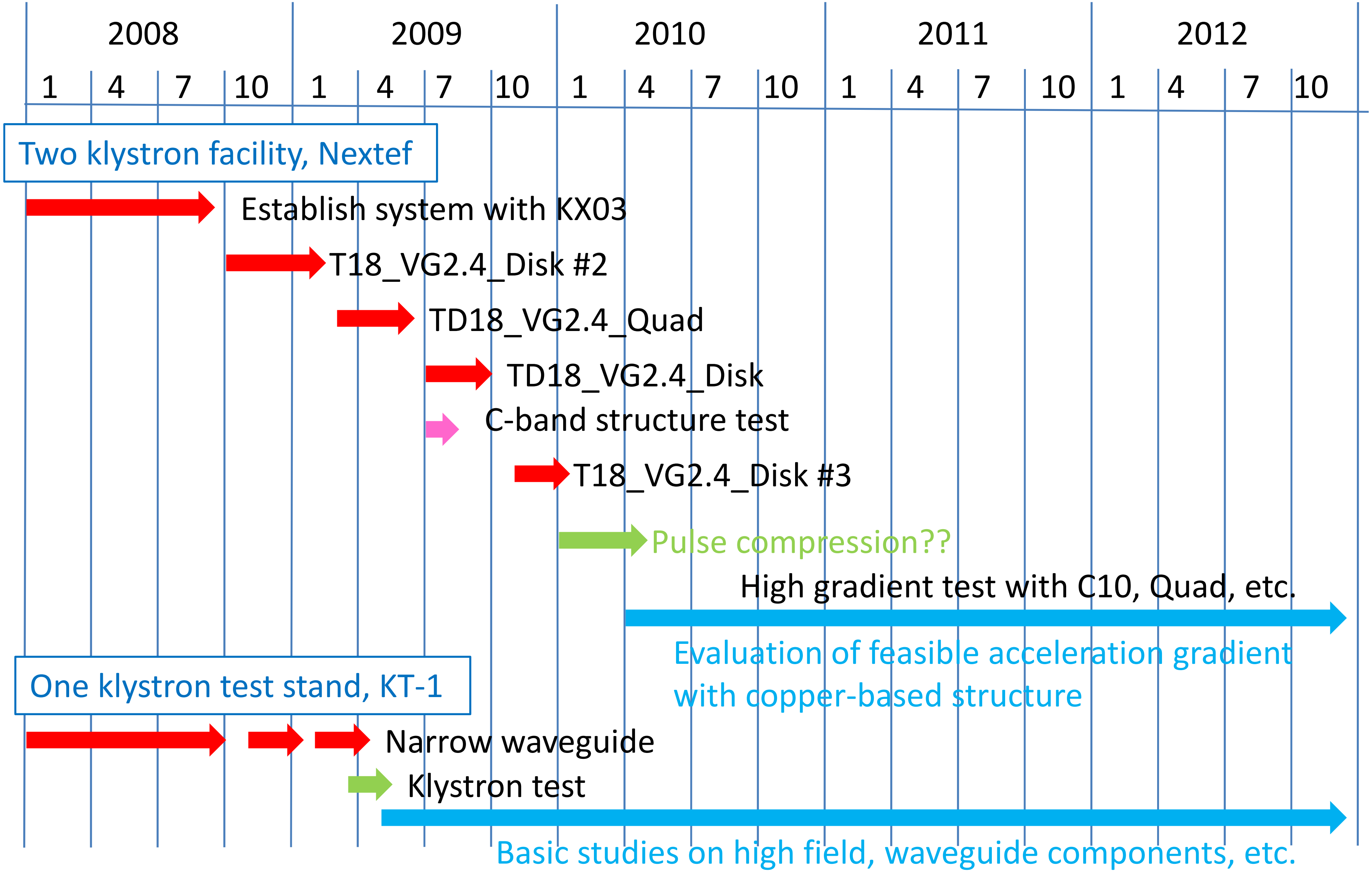
Nextef future planning

- We proceed processing of a series of test structures.
  - With as time-effectively run the facility as possible.
- Pulse compression will be realized in late JFY09
  - TE_{11} 150ns and later adding TE_{0n} for 300ns
- Another bunker will be made in Spring 09
  - C-band program should be proceeded.
  - Then, X-band program will be realized.

Nextef planning as of Nov. 28, '08



Nextef longer-term planning (to be discussed)



X-band Pulse Compression plan

- C-band structure high gradient test should be completed before early stage of the coming summer shutdown.

- If Φ80 circular waveguide is made for the C-band test stand. This can be used for the X-band pulse compression.

- Firstly we realize peak power of 150MW with 150ns pulse width.

    Each klystron produces 30 MW output,

    → 60MW (combined) ×gain 3 = 180MW

    → looks like 150MW available.

- There are some possible options…

    A single High-Q cavity option was proposed by Igor.

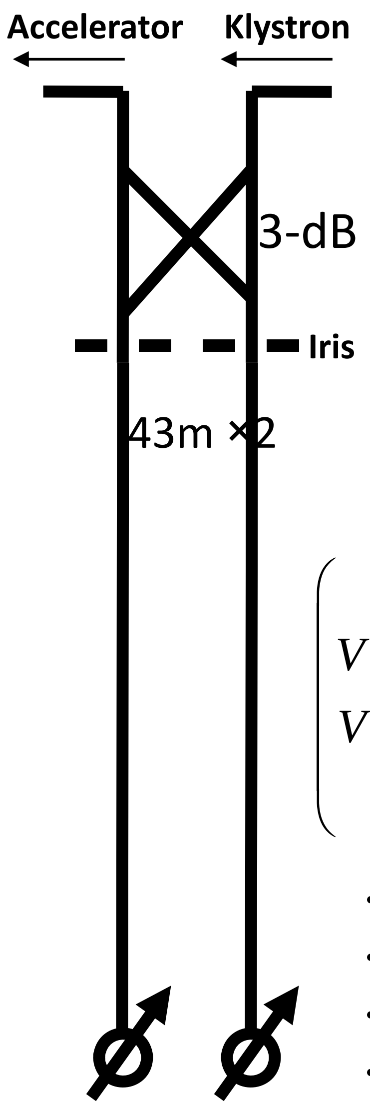
- Basically we decided to take delay line pulse compression.

    High gain, cooperation with C-band project, etc.

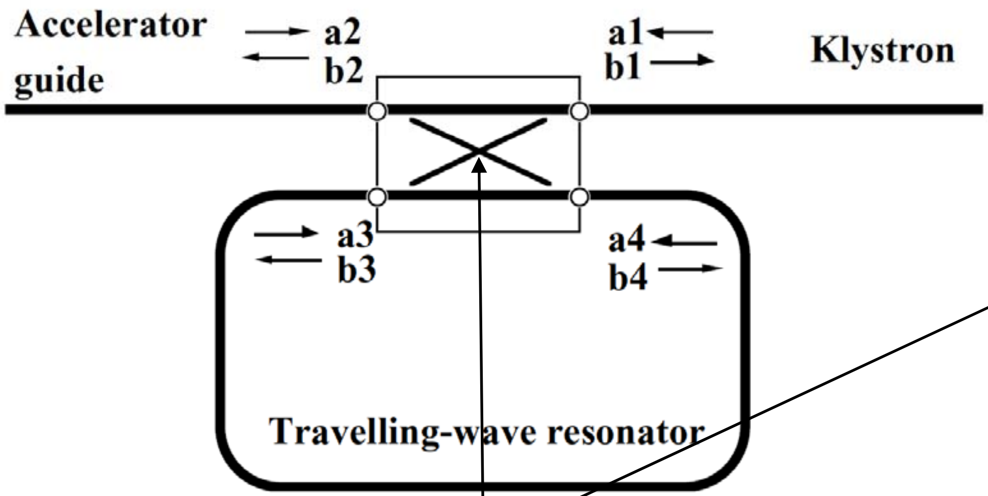
Consideration about Delay Line Type

M.Yoshida

SLED-II

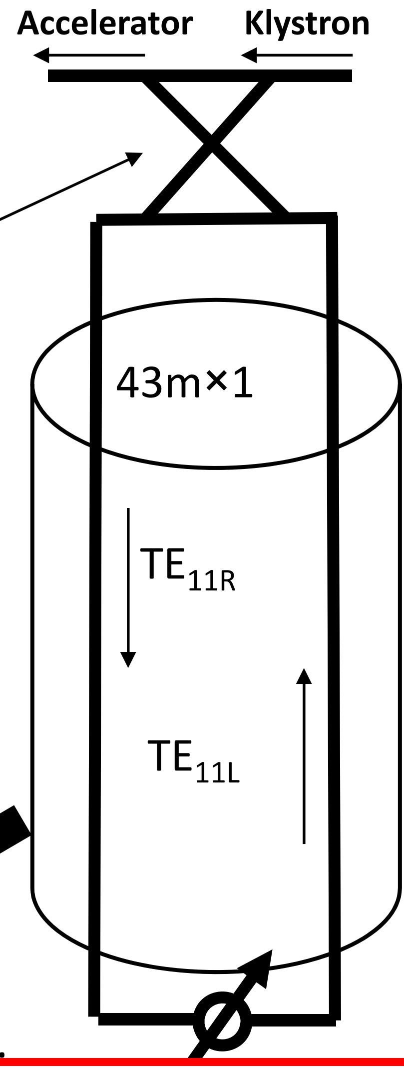


Traveling Wave Pulse Compressor



$$\begin{pmatrix} 0 \\ V(b2) \\ V(b3) \\ 0 \end{pmatrix} = \begin{pmatrix} 0 & \sqrt{1-k^2} & jk & 0 \\ \sqrt{1-k^2} & 0 & 0 & jk \\ jk & 0 & 0 & \sqrt{1-k^2} \\ 0 & jk & \sqrt{1-k^2} & 0 \end{pmatrix} \begin{pmatrix} V(a1) \\ 0 \\ 0 \\ V(a4) \end{pmatrix}$$

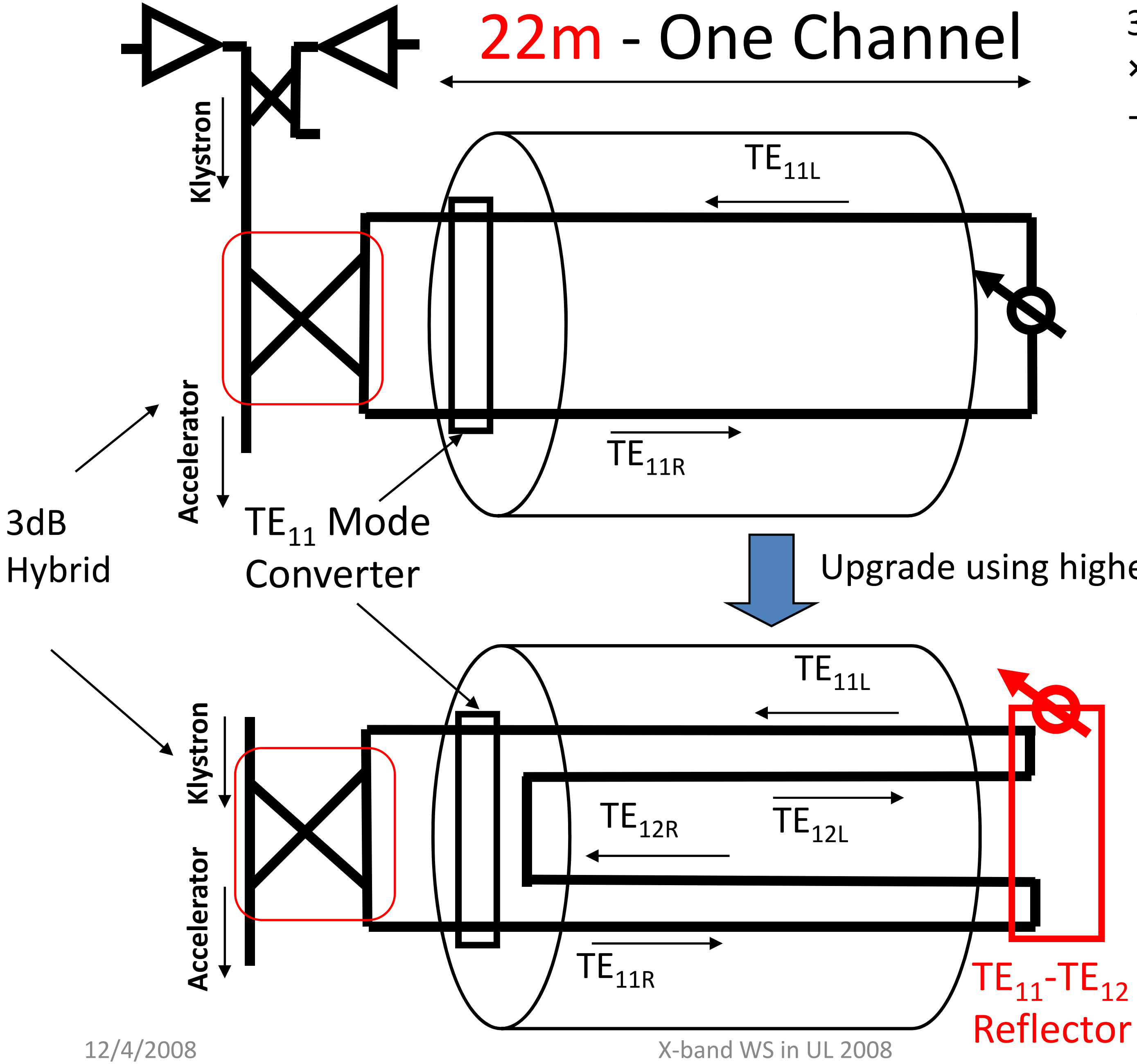
Traveling Wave Single Delay Line Pulse Compressor



- Easy Phase Flip
- Only One Phase Shifter.
- Utilizing C-band Low Loss Line (ϕ80).
- Avoiding to adjust phase difference of different mode.

M.Yoshida

Strategy for Nextef



30MW×2 Klyston
×gain=3
→ 180MW

750ns → 150ns
Gain = 3.6 @ 3dB

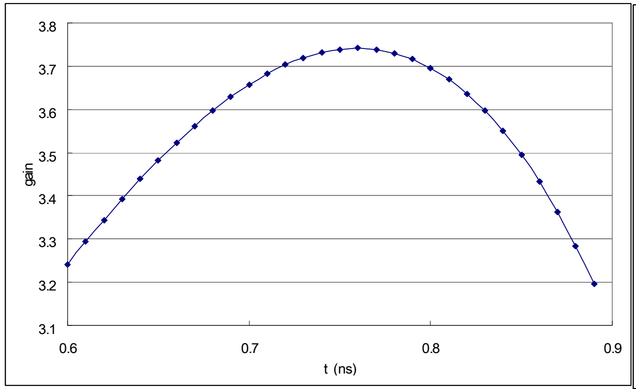
1500ns → 300ns
Gain = 3.3 @ 3dB

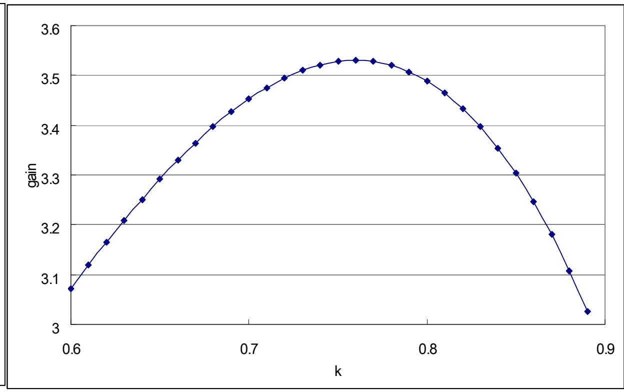
Gain of Traveling Wave Delay Line Pulse Compressor

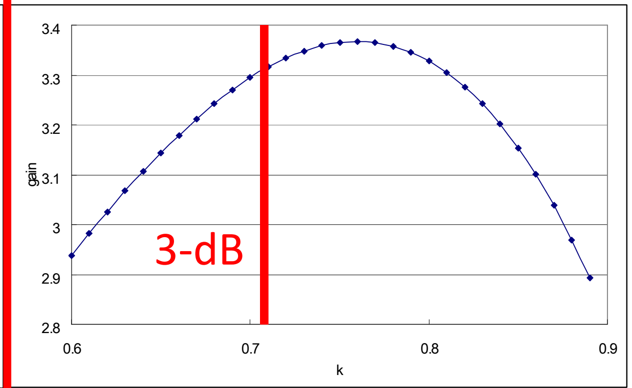
86m×(TE_{01})= -0.24dB/turn

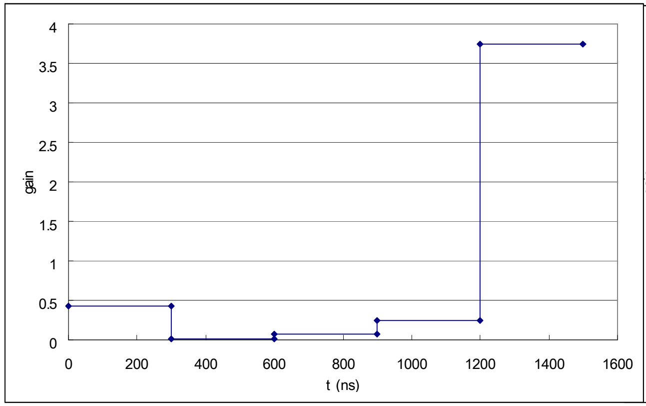
43m×(TE_{01}+TE_{11})= -0.44dB/turn

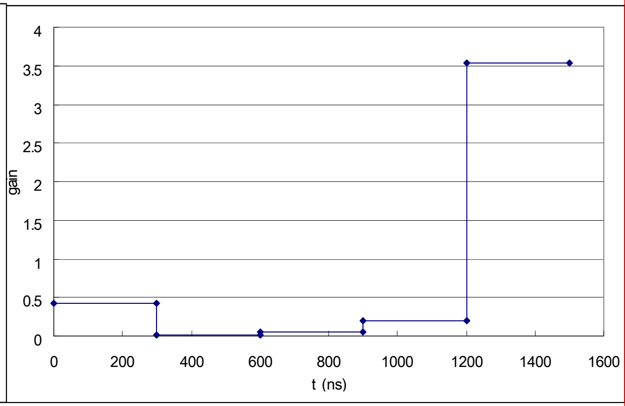
22m×(TE_{11R}+TE_{11L}+TE_{12R}+TE_{12L})
= 43m× (TE_{11R}+TE_{11L}) = -0.6dB/turn

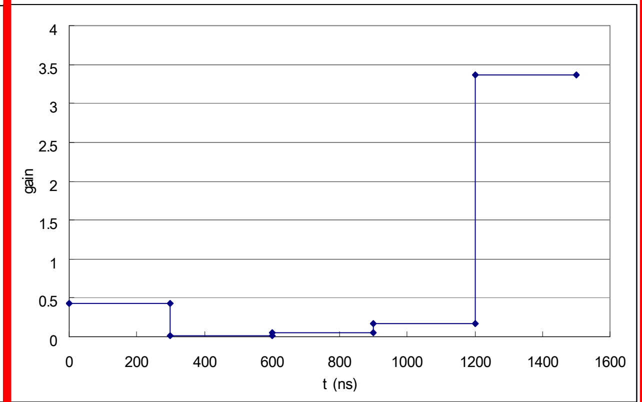












Gain=3.74

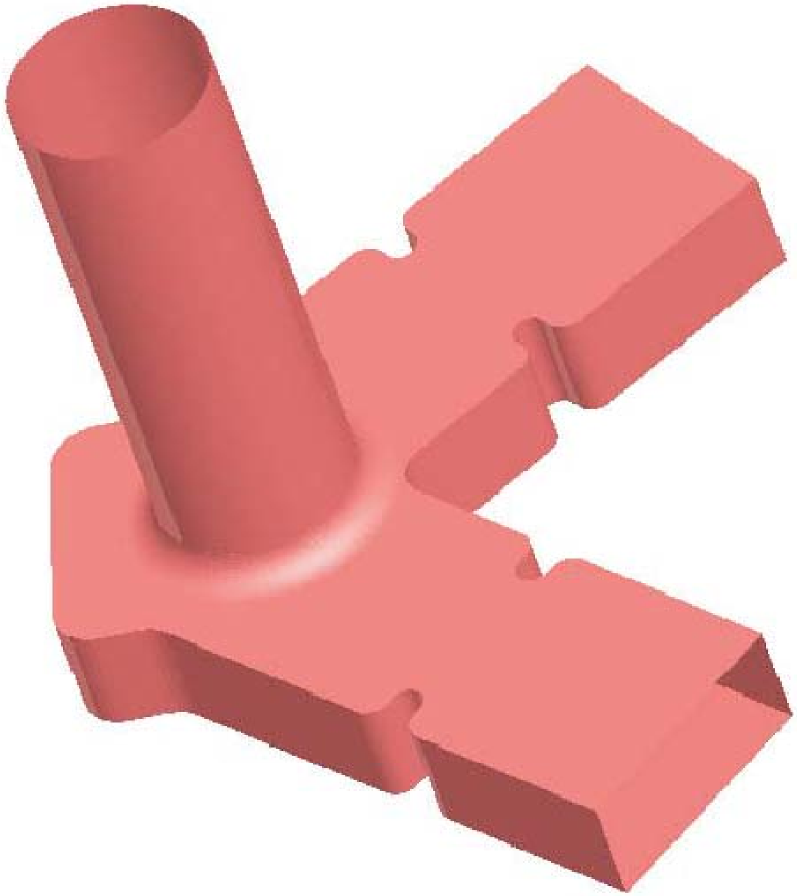
Gain=3.53

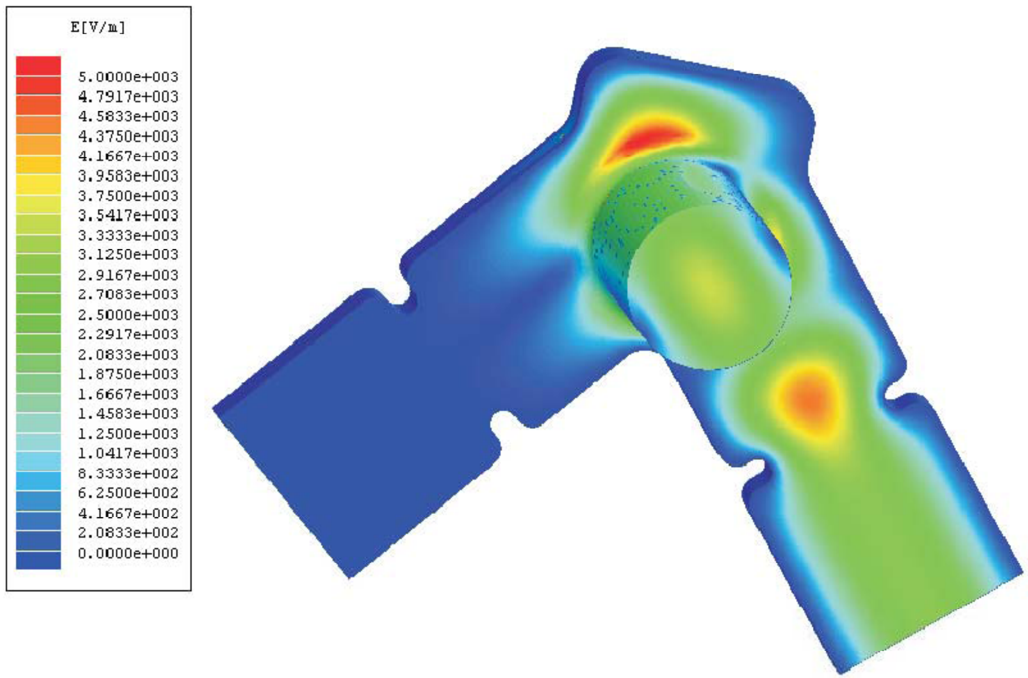
Gain=3.35
(Gain=**3.29** @ 3-dB Hybrid)

Practical solution by 4-mode 22m-pipe
with using existing 3dB hybrid.

Mode Converter

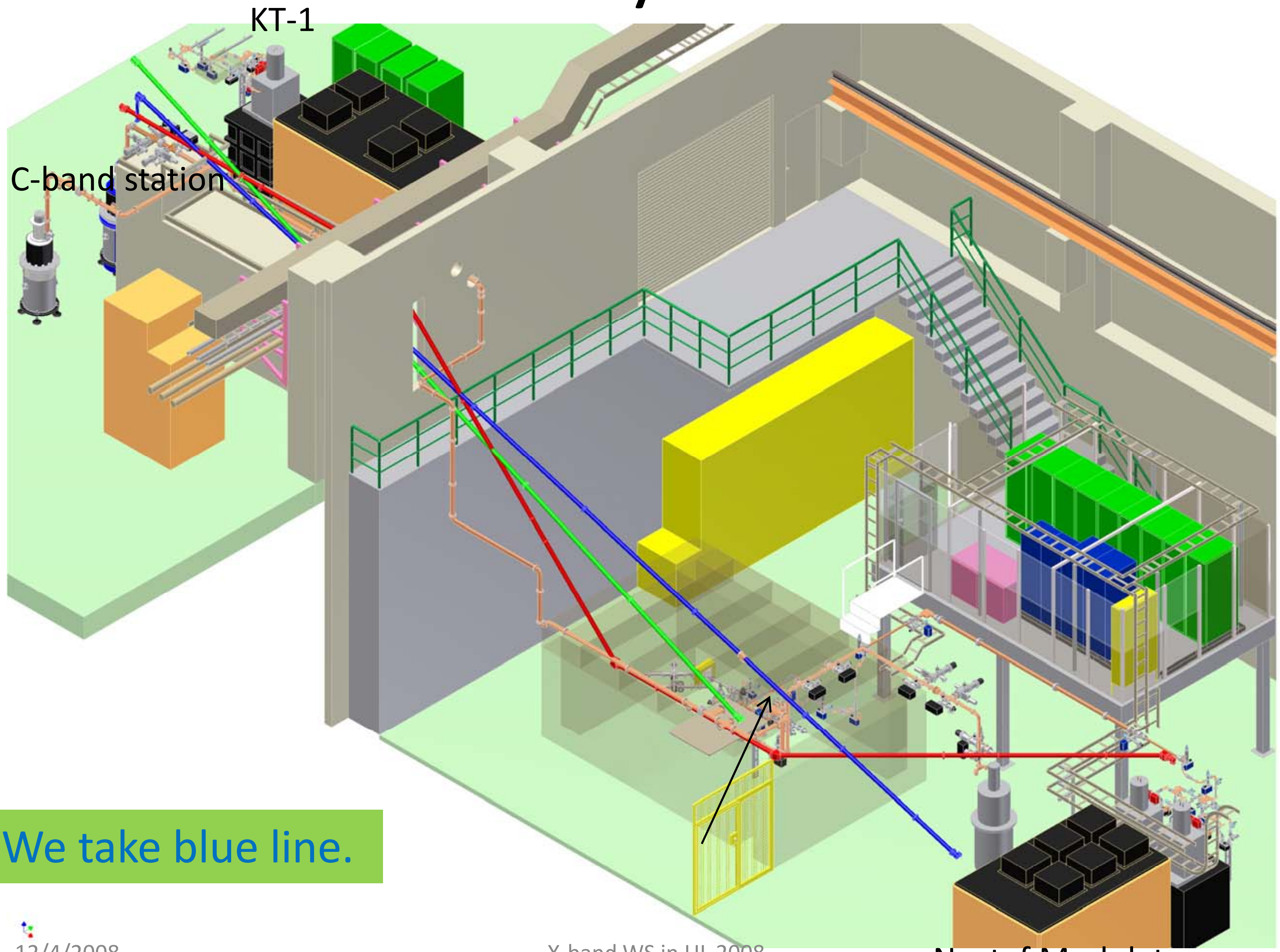
WR90 Rectangular TE10 → Circular TE11(R)





S.Kazakov

Layout



We take blue line.

X-band klystrons

We have three klystrons in operation.
A spare re-built klystron needs to be conditioned.

Our X-band PPM klystrons have a limit in available peak power and pulse width due to the RF pulse tearing.

XL-4: We need big money!

Multi-Beam Klystron: The design is almost at hand, but we have no budget to develop it.

An idea was proposed to use our solenoid klystrons with SC magnet. These klystrons have not shown (severe) pulse tearing events. These can be spares but detailed design has not yet started.

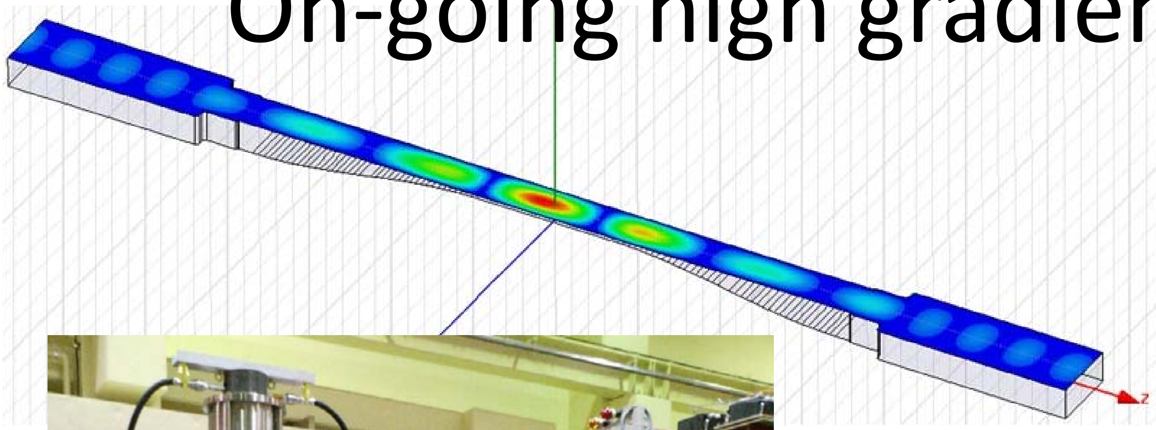
Summary of Nextef
mission, status and possible further activities

- Mission
  - Close collaboration with CLIC structure developments
  - Basic high gradient study
- Nextef operation
  - Run 24 hr/day during linac operation
  - Limited operation during linac maintenance
  - Should coexists with C-band structure activity
- Further development
  - Pulse compression in 2009-2010 >150MW, 300ns
  - Another test stand using power switching
  - Preparing more klystrons? We do not have any definite plan yet.

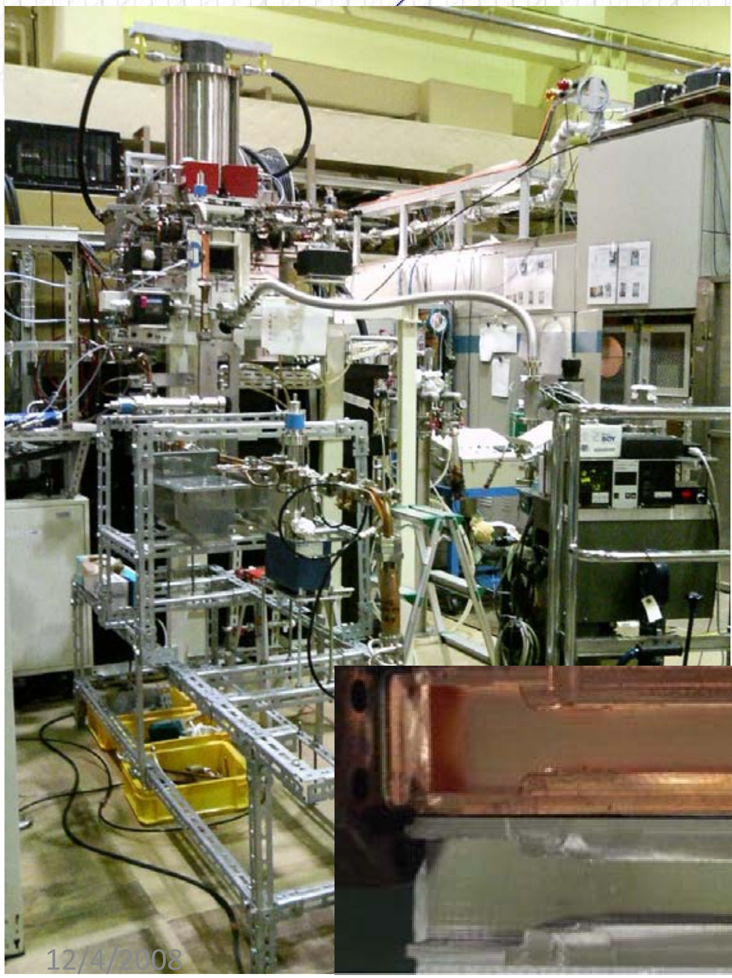
Basic research at KT-1

- Programs which uses present KT-1
  - Typical power ratings is 50MW, 400ns, 50Hz
  - High gradient study in narrow waveguide
  - Testing klystrons
  - Waveguide component test up to medium power
- Pulse compression is also possible
  - Thinking stage
  - High power test of waveguide components will become practical

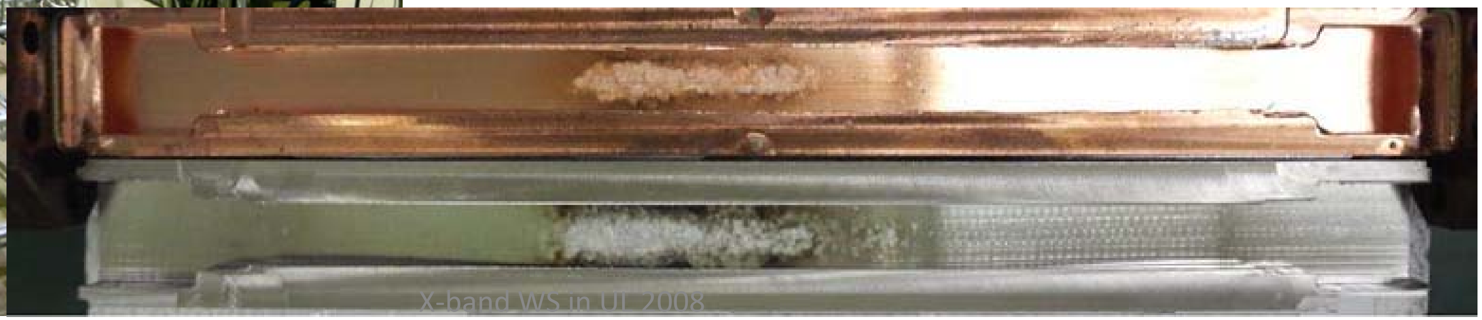
On-going high gradient study at KT-1



Yokoyama presentation at LINAC08

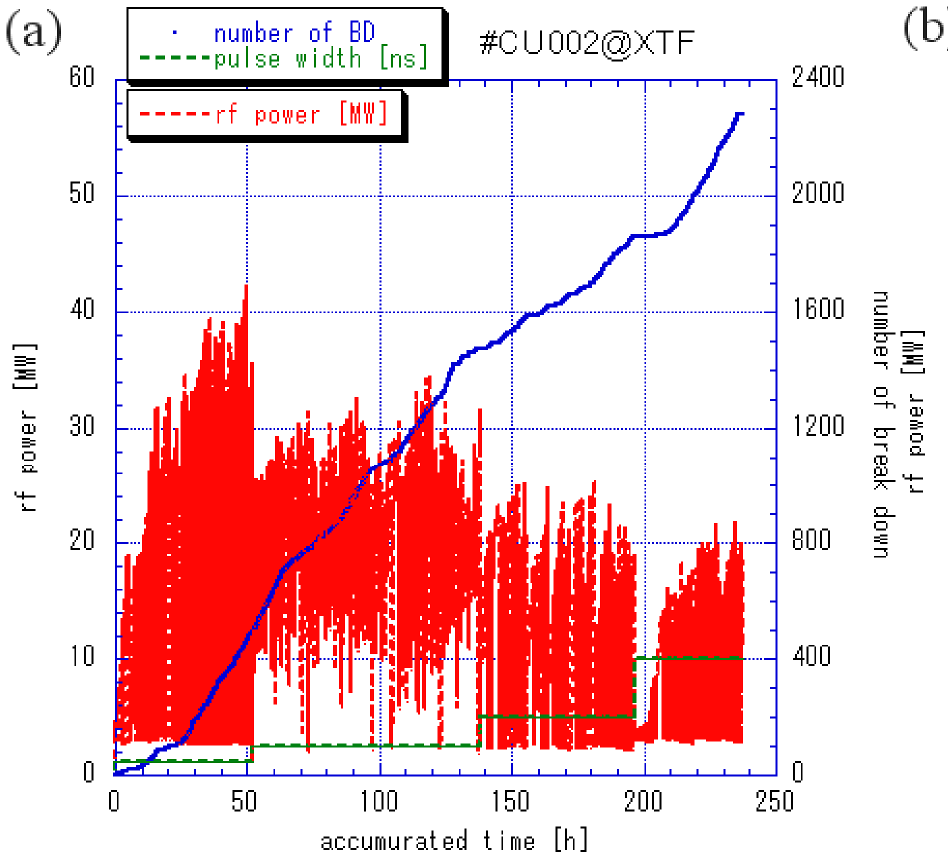


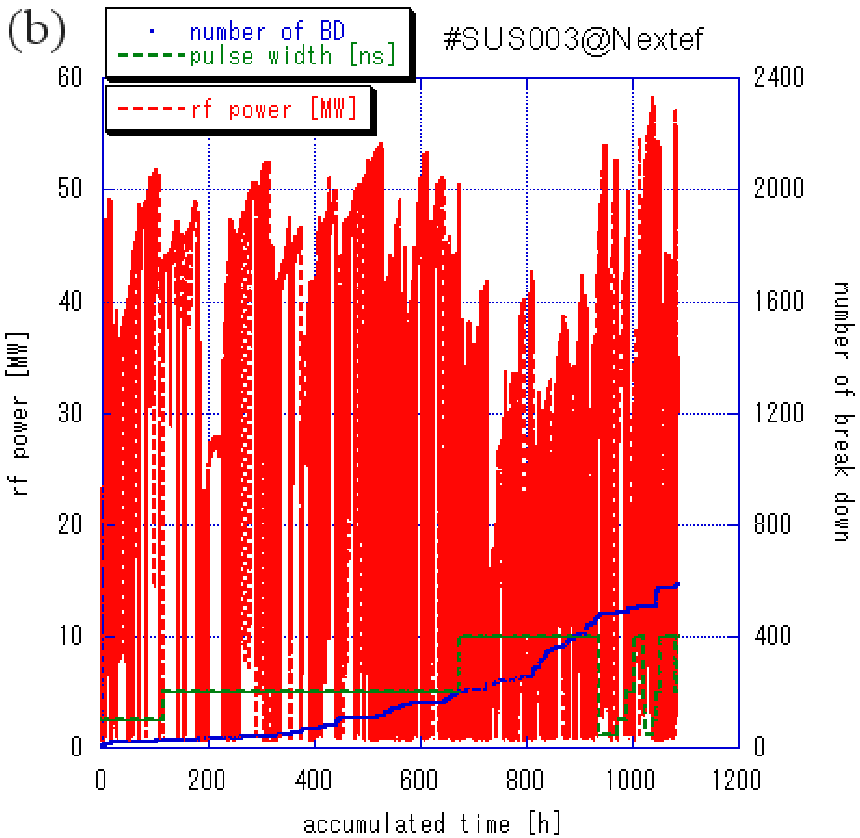
Established system with measurement of low breakdown rate.
Tasted copper and stainless steel.
Now study copper next with this established system trying to compare various following materials.



Our processing differs between copper and stainless, but .....

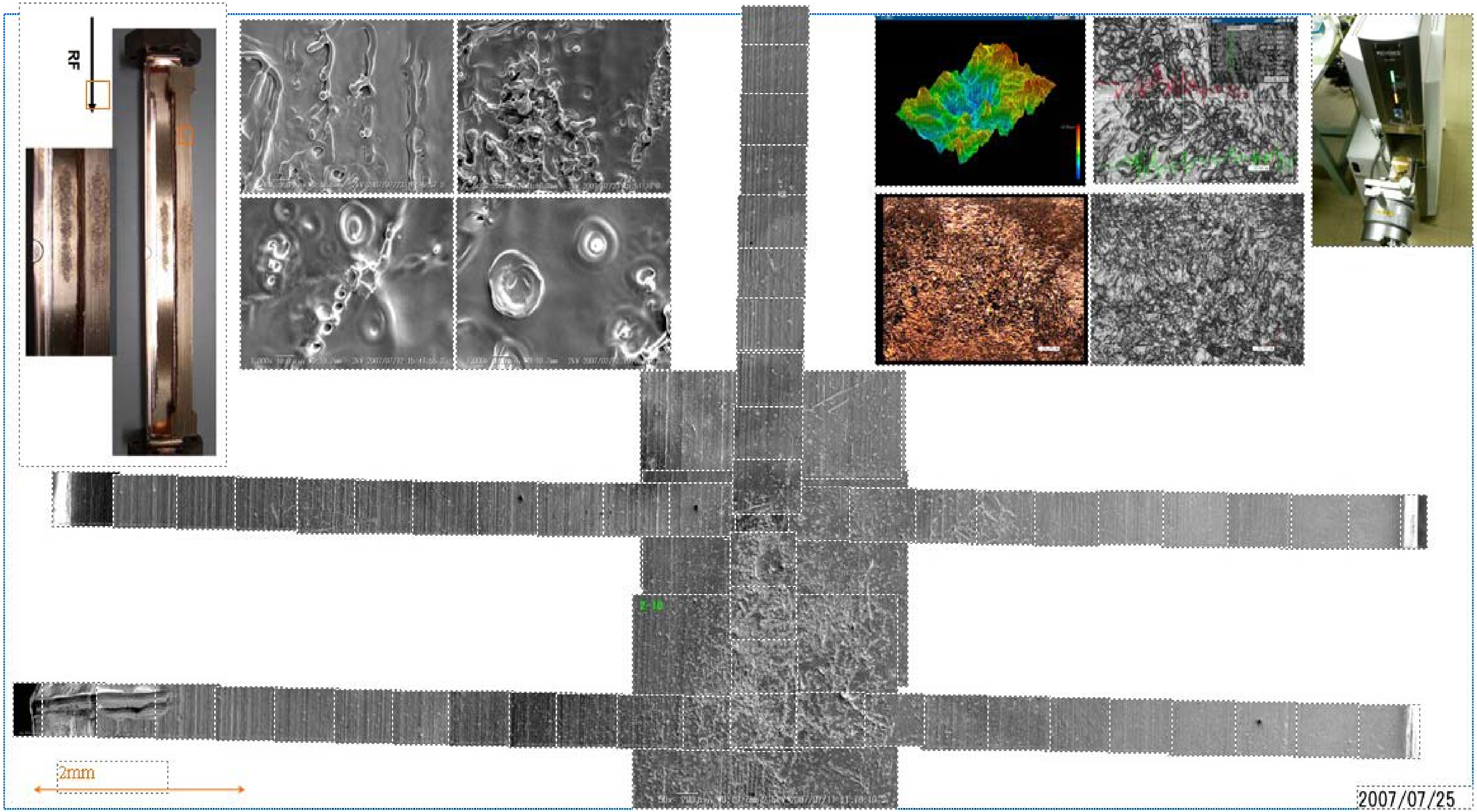
We want to compare the two materials more carefully again.
We actually did these tests at different systems.



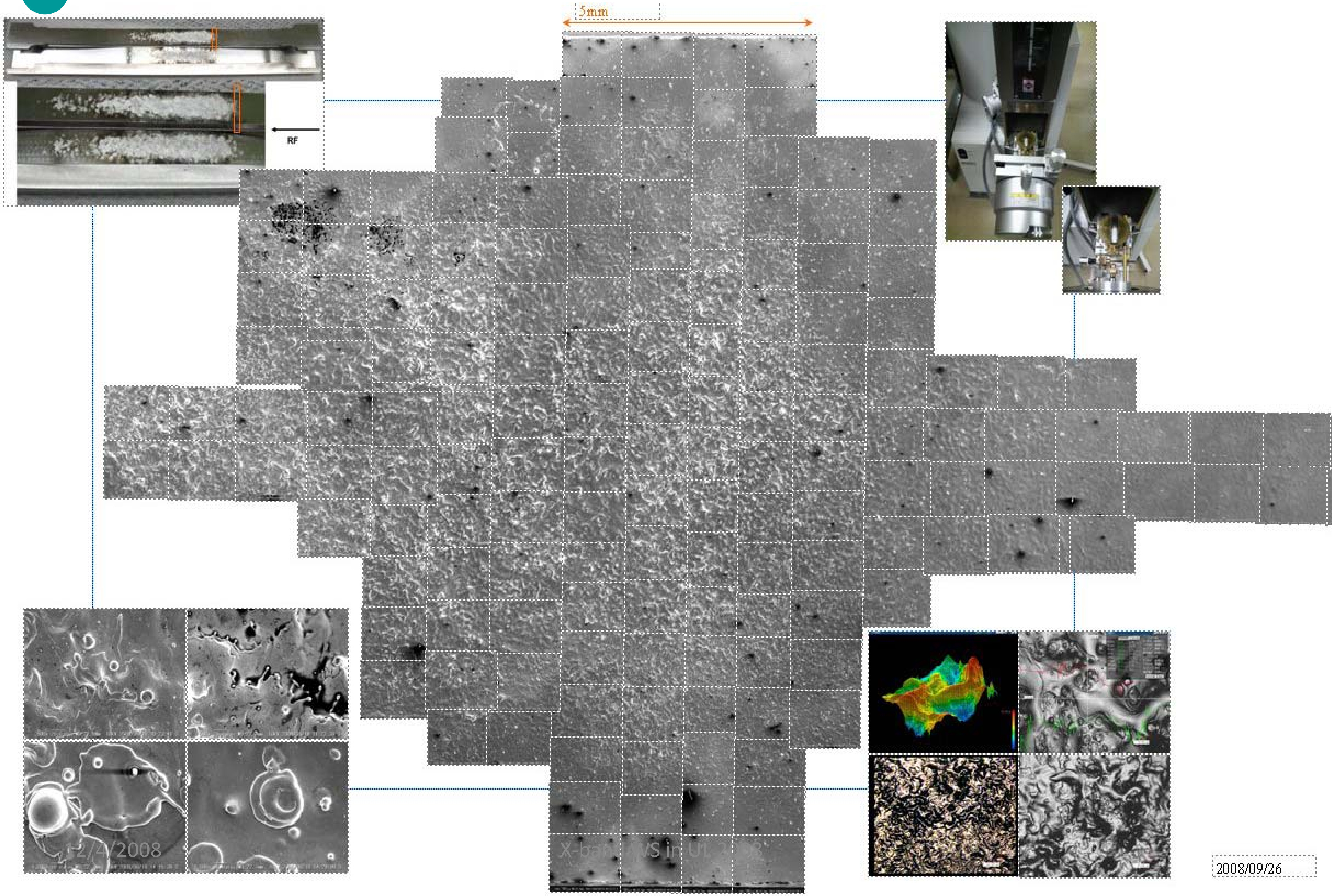


#CU002

Inspection of surface after testing.
Evaluation of surface and arcs etc.

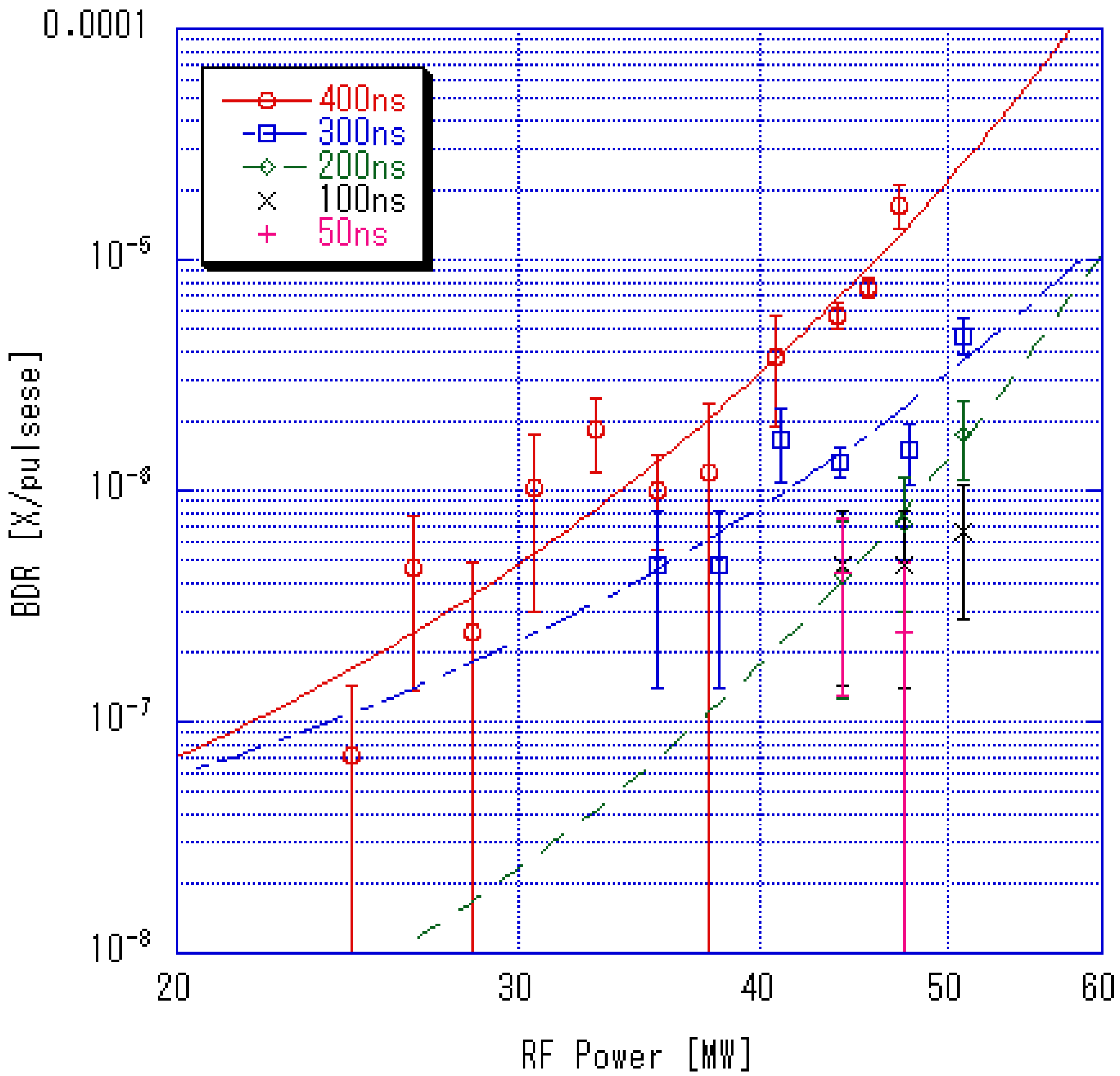


#SUS003



2008/09/26

Evaluation of breakdown rate of SUS-003



Basic surface study

- Higashi has been preparing samples for SLAC
  - For pulse heating
  - For single-cell high gradient test
- We may address study after additional test area is established
  - Effect to the initial processing characteristics
  - From surface quality view point
  - Hardness, rinsing, baking, single crystal, ….

Additional topic 1:

Possible replacement of TWT power amplifier by GaN HEMT

We suffer from the life of TWTA.

GaN HEMT (High Electron Mobility Transistor) is a promising device for producing several 10W CW power in X band.

Toshiba demonstrated 81W(CW) at 9.5GHz and 65W at 14.5GHz.

We asked to modify it to 11.4GHz. It should cover 12GHz with a slight different tuning frequency. It will be delivered to KEK in next March.

Technical Specifications

Product Characteristics	TGI1414-50L	TGI0910-50
Frequency	14.0 - 14.5GHz	9.5-10.5GHz
Output Power	47.0dBm	47.0dBm
Linear Gain GL(typ.)	8.0dB	9.0dB
Drain Current VDS/IDS(typ.)	+24V/5.0A	+24V/4.5A
Efficiency	29%	35%
Package	7- AA04A	7- AA04A

Specification for 11424MHz

TOSHIBA
MICROWAVE SEMICONDUCTOR
TECHNICAL DATA

MICROWAVE POWER GaN HEMT
TGI1011-50-771
Draft

FEATURES

- **HIGH POWER**
  Pout=47.0dBm at Pin=41.5dBm
- **HIGH GAIN**
  GL=9.0dB at 11.374GHz to 11.474GHz
- **BROAD BAND INTERNALLY MATCHED HEMT**
  HERMETICALLY SEALED PACKAGE

RF PERFORMANCE SPECIFICATIONS (Ta= 25°C)

CHARACTERISTICS	SYMBOL	CONDITIONS	UNIT	MIN.	TYP.	MAX.
Output Power	Pout	VDS= 24V	dBm	46.0	47.0	—
Drain Current	IDS1	IDSset≅1.5A	A	—	5.0	6.0
Power Added Efficiency	η_{add}	f = 11.374 to 11.474GHz @Pin = 41.5dBm	%	—	30	—
Linear Gain	GL	@Pin = 20dBm	dB	7.5	9.0	—
Channel Temperature Rise	ΔTch	(VDS X IDS1 + Pin – Pout)X Rth(c-c)	°C	—	130	160

Recommended gate resistance(Rg) : Rg= 3.3 Ω(TYP.)

ELECTRICAL CHARACTERISTICS (Ta= 25°C)

CHARACTERISTICS	SYMBOL	CONDITIONS	UNIT	MIN.	TYP.	MAX.
Transconductance	gm	VDS= 5V IDS= 5.0A	S	—	4.5	—
Pinch-off Voltage	VGSoff	VDS= 5V IDS= 23mA	V	-1	-4	-6
Saturated Drain Current	IDSS	VDS= 5V VGS= 0V	A	—	15	—
Gate-Source Breakdown Voltage	VGSO	IGS= -10mA	V	-10	—	—
Thermal Resistance	Rth(c-c)	Channel to Case	°C/W	—	—	1.6

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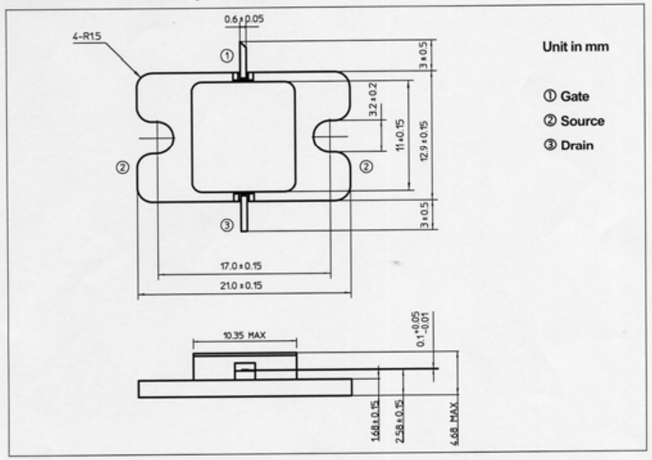
TOSHIBA CORPORATION

August, 2008

ABSOLUTE MAXIMUM RATINGS (Ta= 25°C)

CHARACTERISTICS	SYMBOL	UNIT	RATING
Drain-Source Voltage	VDS	V	50
Gate-Source Voltage	VGS	V	-10
Drain Current	IDS	A	15
Total Power Dissipation (Tc= 25 °C)	PT	W	140
Channel Temperature	Tch	°C	250
Storage	Tstg	°C	-65 to +175

PACKAGE OUTLINE (7- AA04A)



HANDLING PRECAUTIONS FOR PACKAGE MODEL

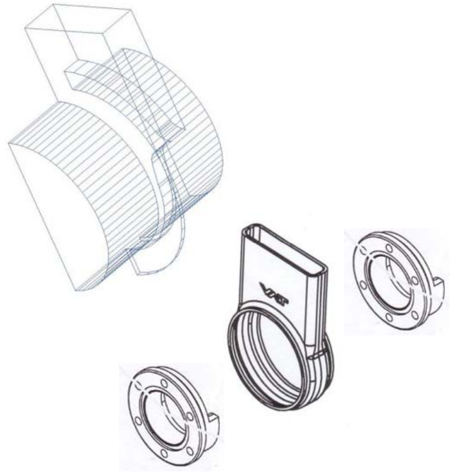
Soldering iron should be grounded and the operating time should not exceed 10 seconds at 260°C.

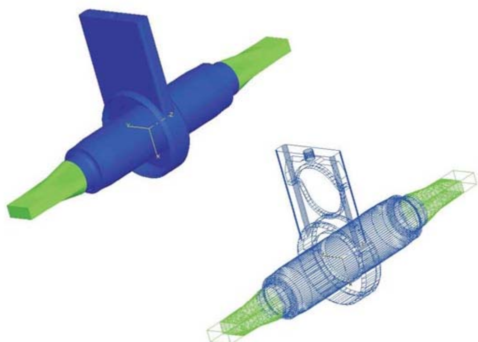
Additional topic 2:

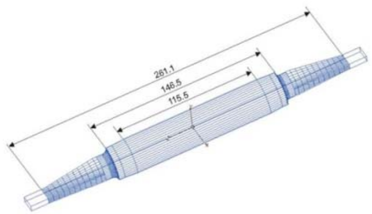
Compact waveguide valve designed

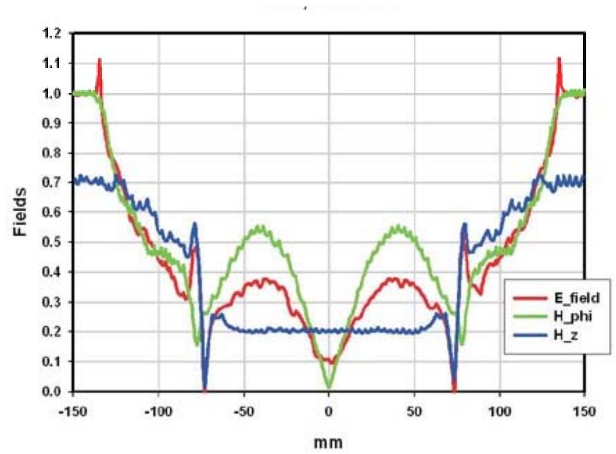
Sergey Kazakov

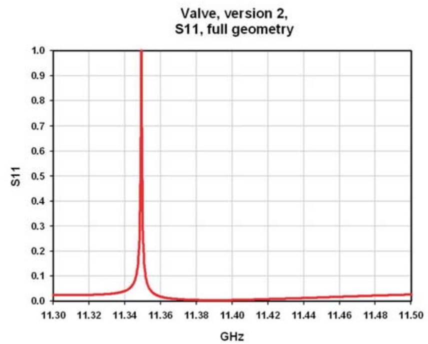
TE11 mode to make the device compact
Using VAT existing GV with some modification such as
Edge rounding, vacuum seal device far from pipe, etc.

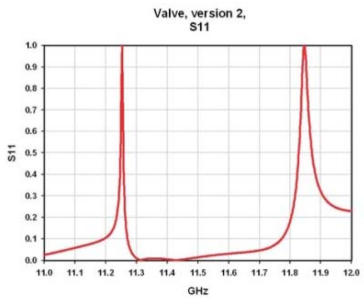












Now under mechanical design
To be made in this fiscal year and to be tested soon.

If not work, we follow TE0n SLAC/CERN design.

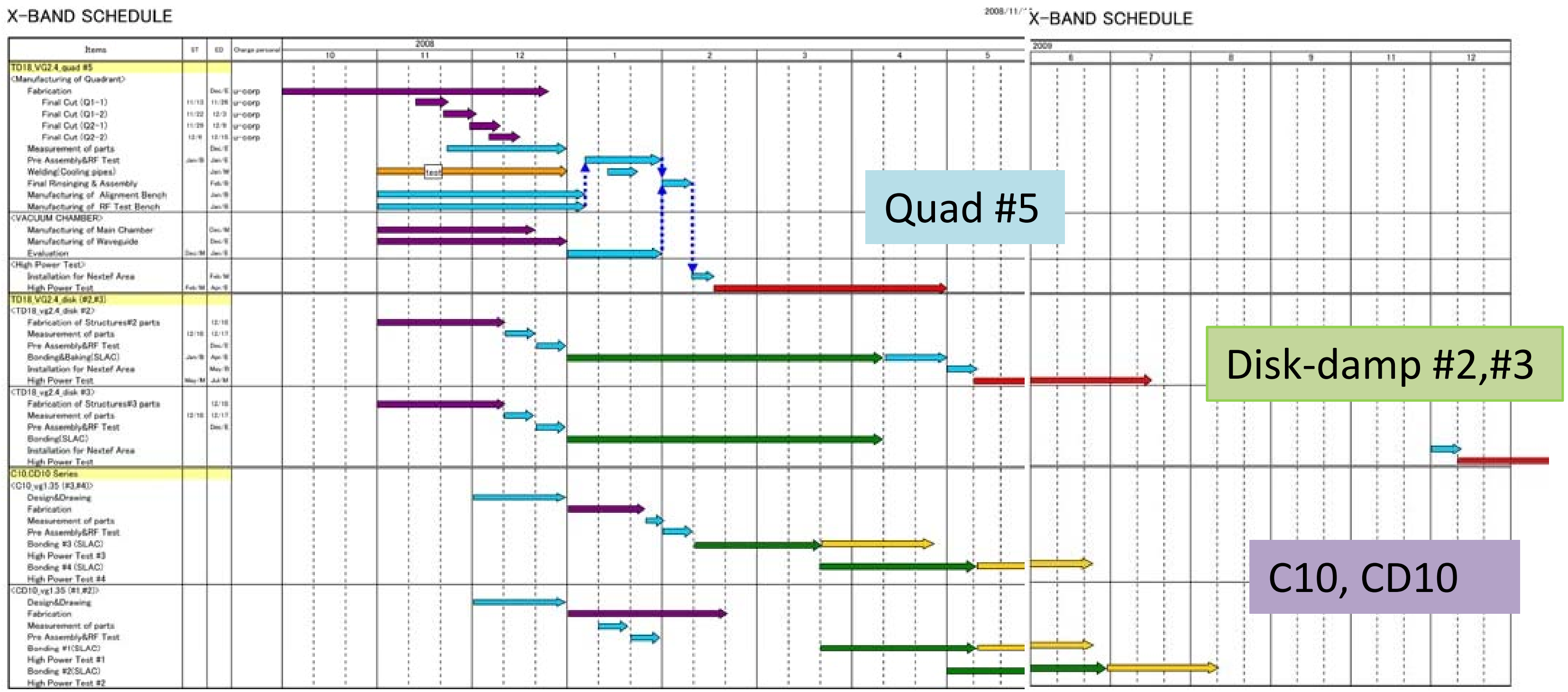
Strategy of structure fabrication at KEK

- Re-establish GLC/NLC structure fab technique
  - 60-100MV/m
- Extend it to heavily damped structure for CLIC
  - Disk damp confirmation
- Learn about fabrication by all milling
  - Study high gradient performance
  - Study mass production feasibility
- Discuss about the practical candidate
  - For near future application in a few years

Structure study in collaboration

- Maximally utilize the present framework
  - CERN-SLAC-KEK
  - Design-fabrication-test
  - Firstly take KEK-SLAC fabrication method established as of GLC/NLC
  - Get info of extreme gradient / practical gradient
  - Cross-check the performance / fabrication
- Welcome contribution
  - Any idea and experimental effort at Nextef

Structure fabrication schedule Nov. 27, 2008



We are happy (!?) that the progress and schedule are reviewed and discussed once a month under CERN management.

We delayed quadrant preparation by a month.

Disk-damp fabrication is delayed but will be ended by the end of this year. They are to be shipped to SLAC in early next year.

C10, CD10 are following Disk-damp → delays accordingly.

CLIC_VG1 (T18_VG2.4_Disk)

Disk-undamped structures fabricated with the GLC/NLC technology

- #1 tested at SLAC
  - Processed 120MV/m, BDR increased after 1200hrs
- #2 being tested at KEK
  - Now staying at 80MV/m for a month operation
- #3 and #4 in fabrication at SLAC
- #3 as the test after Nextef established
  - Fabrication the same as #1,#2
  - Will be tested at KEK
  - Increase statistics
- #4 taste the vacuum baking effect
  - #4 skip vacuum baking at 650C
  - Will be tested at KEK

Disk-damp fabrication

For the study of the effect of damping waveguide, opening increases pulse heating.

- Started with the same technology as T18_VG2.4_Disk
  - Material
    - OFC
  - Machining
    - Usual turning for disk
    - Usual milling for coupler of mode converter type
  - Surface treatments
    - SLAC does all in the same manner as T18_VG2.4_Disk
    - CP, DB and VAC baking
- Take the same method but with milling in each cell
  - Mechanical design by KEK
  - Fabrication study finished

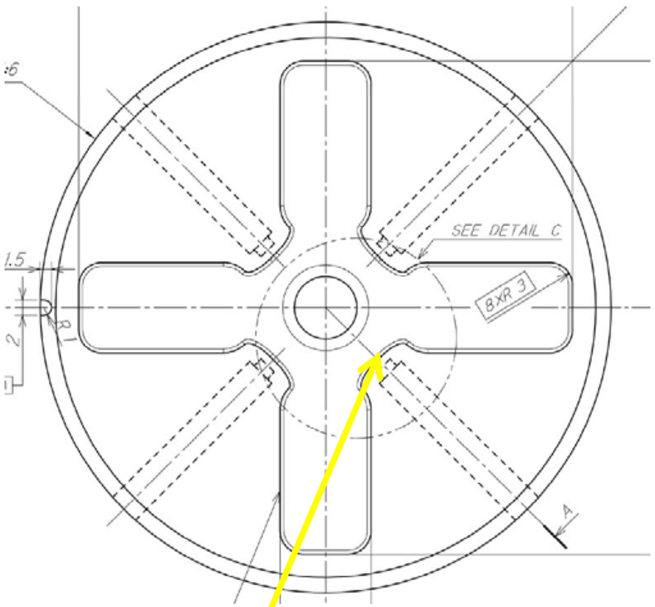
Milled surfaces are different from disk-undamp

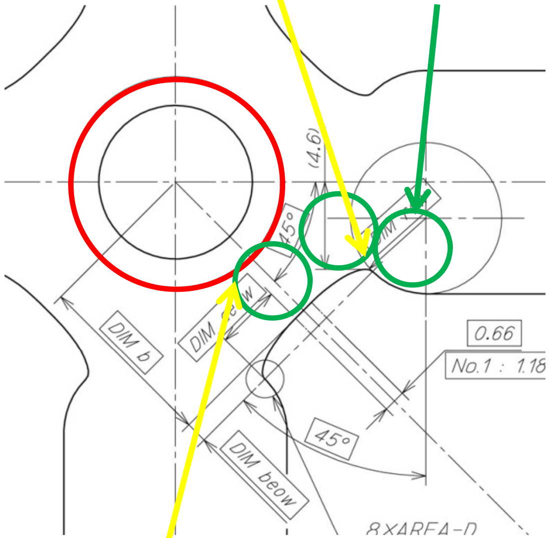
Milled surface at highest H field.

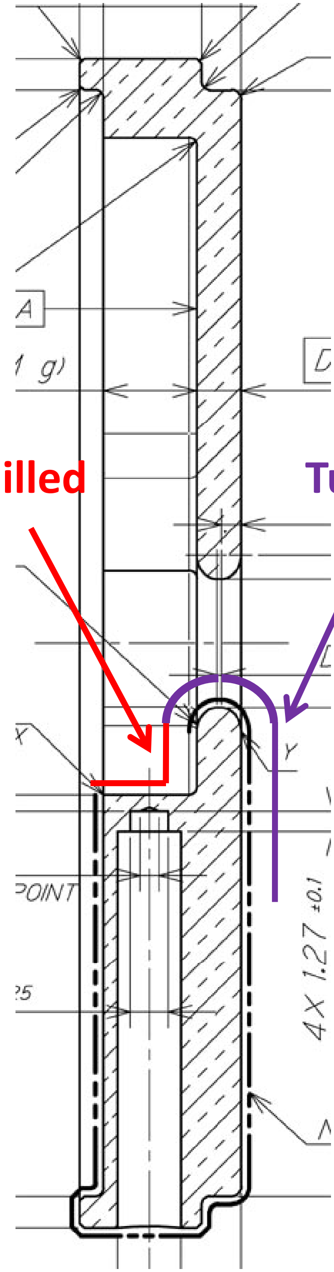
Tool dia.

Milled

Turned



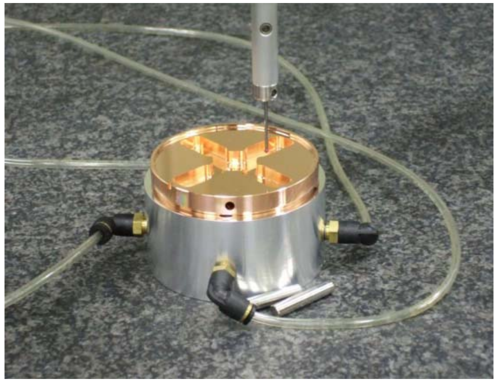


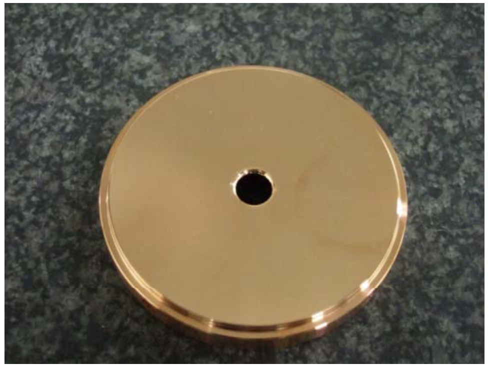


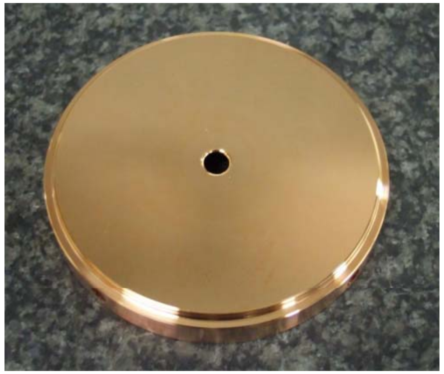
Dimple-tuned surface at high H field.

Milled surface close to highest E field.

TD18_VG2.4_Disk   Fabrication test







Cell #1

Cell #19

Concerns in
- Dimension
- Flatness
- Burrs

are cleared.

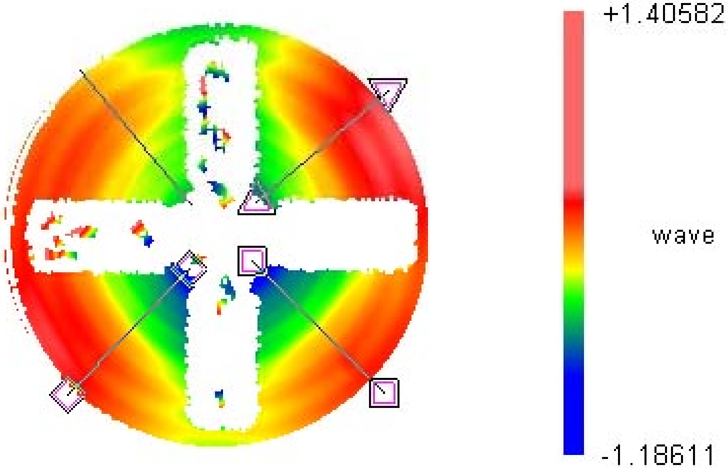
Flatness

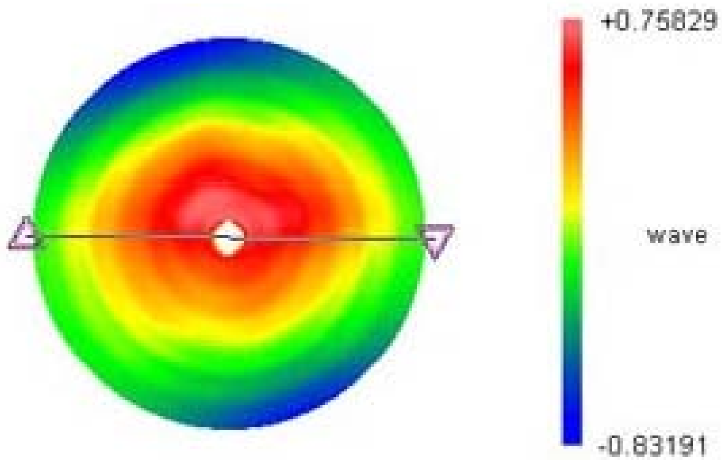
Use better lathe

Flatness better than 1.5micron in free position

Flatness becomes better <1 micron when pushed onto the flat surface.

Flatness if OK.





Cares on dimensions and burrs

- Dimensions
  - Adjust perpendicularity of the milling tool
- Burrs
  - Use KEK’s single-crystal diamond for end surface cut at the final step
  - Use diamond from 0.1mm undercut to final
- Now we started the actual final fabrication stage.
  - Being fabricated now.
  - Mechanical checking by vendor and KEK.
  - Electrical checking by bead pull at KEK.
  - Shipping to SLAC at the beginning of next year, at earliest.

C10 and CD10

- We are waiting for TD18_VG2.4_Disk finish.
  - Actual starting date is delayed.
- We take the same fabrication method.
  - Start C10 with all turning.
  - Second (later) trial may be with milling as CD10.
  - CD10 the same as TD18_VG2.4_Disk.
- A set of mode convertor couplers are being made by SLAC.
- Full mechanical design of the setup is in progress.
- Should discuss
  - Who, when and how to bond and vacuum treat?
  - Where and how to test?
  - This is somewhat independent from CERN-SLAC C10-series test. So we have some freedom to test in a different view point.

Quad fabrication and preparation of high gradient test

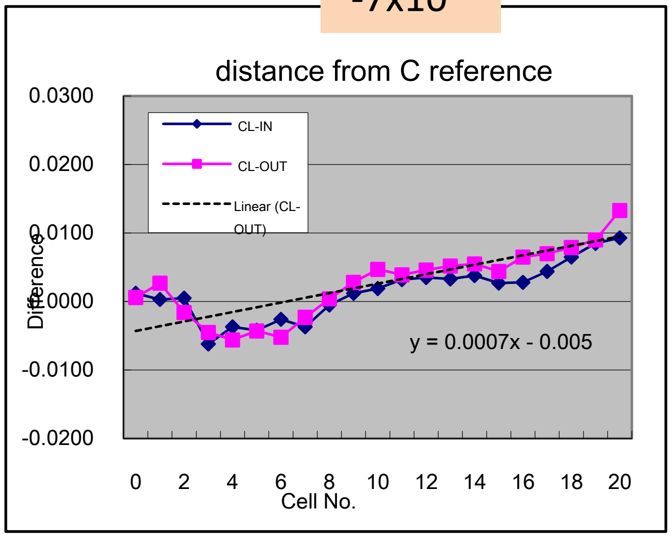
- Present mission
  - Fabrication with all ball point milling
  - Assembly for high power realization
  - Non heat treated cavity in a vacuum vessel
- Discussions to be made afterwards
  - Feasibility for near future LC
  - Pros and cons in general
  - Precision alignment issue comes after high power

Status of four quadrants

- Brushed up the machining technique
  - Longitudinal: ~5 microns / 200mm
    - We think this controllability necessary to assure the precision of the overall 3D surface creation, though do not know for sure.
  - Transverse direction: within ± a few microns
- Actual fabrication of four quadrants
  - Four quads are called Q1-1, Q1-2, Q2-1, Q2-2.
  - Started final cutting in mid. November
  - Two quads Q1-1, Q1-2 were delivered to KEK.
  - Its quality the same as the test one, Q1-0. Stability confirmed.
  - Four quads will be delivered to KEK by mid Dec.
- Assembly and tuning etc.
  - Will be done in January.
  - Hope to be ready to install in February.

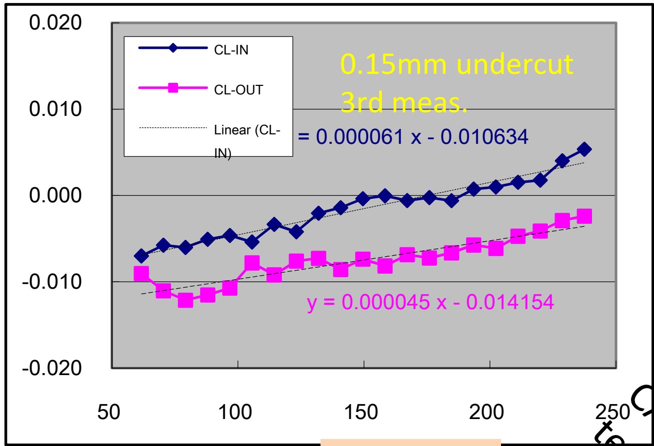
As of CLIC08

Improvement of longitudinal dimension control



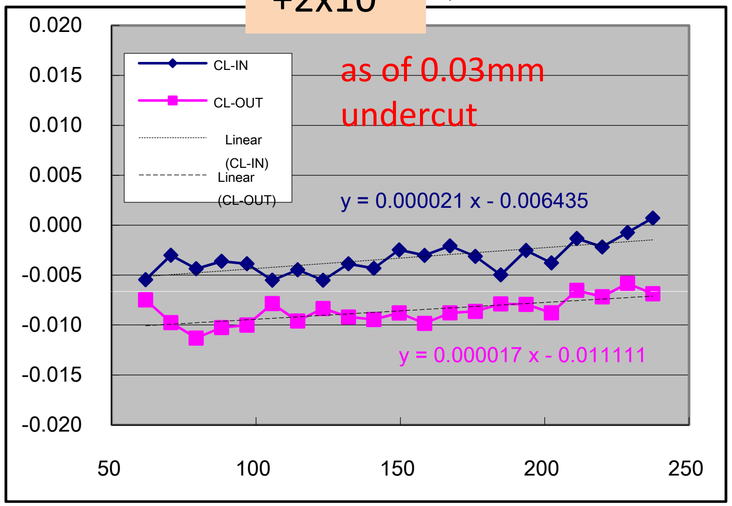
Machine tune up.

-7×10^{-4}

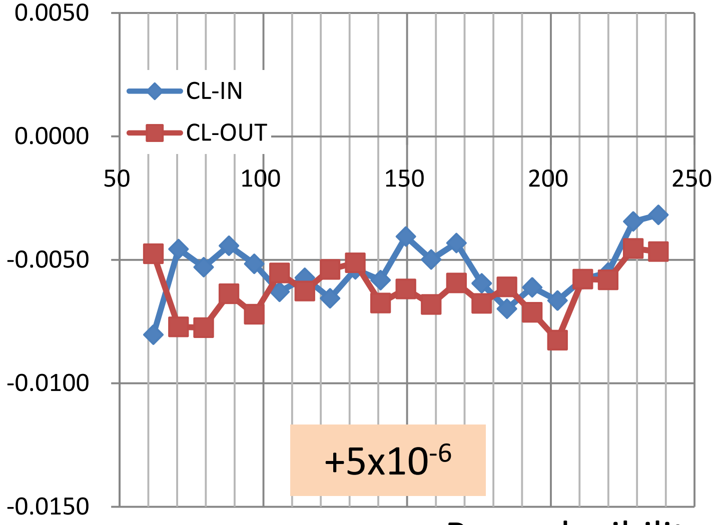


$+5\times10^{-5}$

CAM temp. correction



$+2\times10^{-5}$

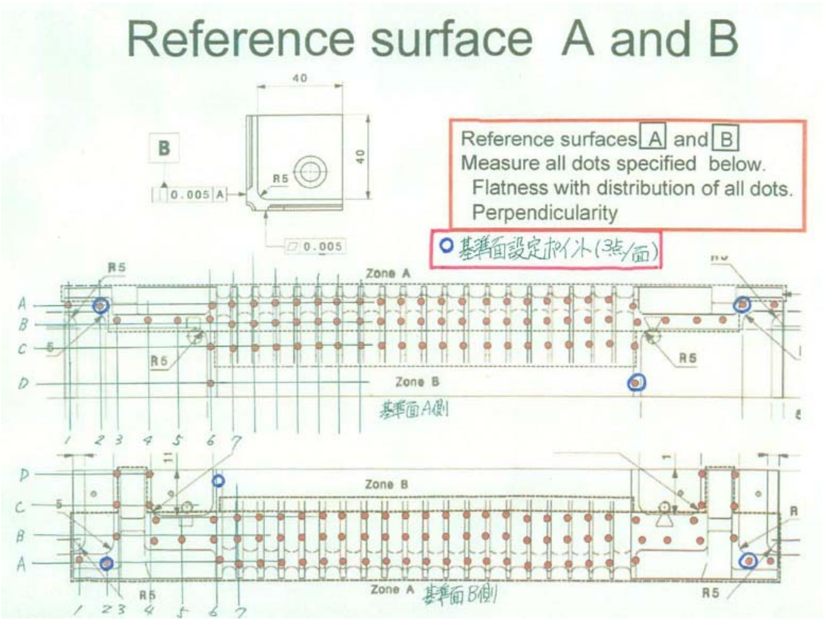


$+5\times10^{-6}$

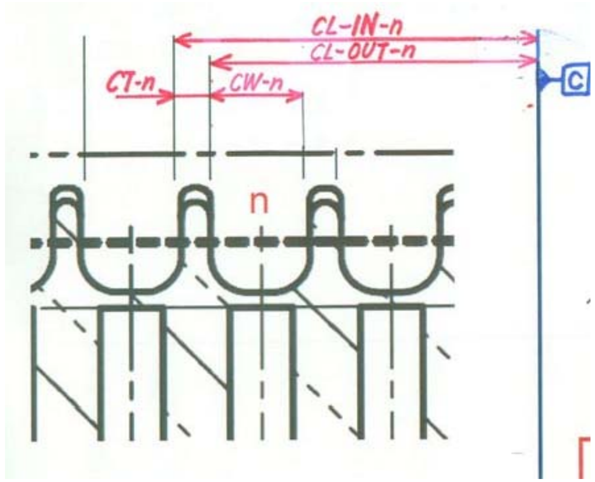
Reproducibility
~ 4μm /200mm

Dimensions to be confirmed

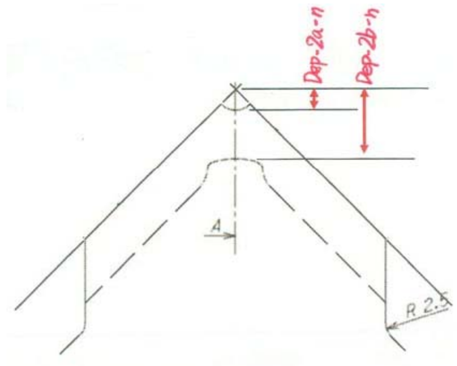
Flatness



Longitudinal position



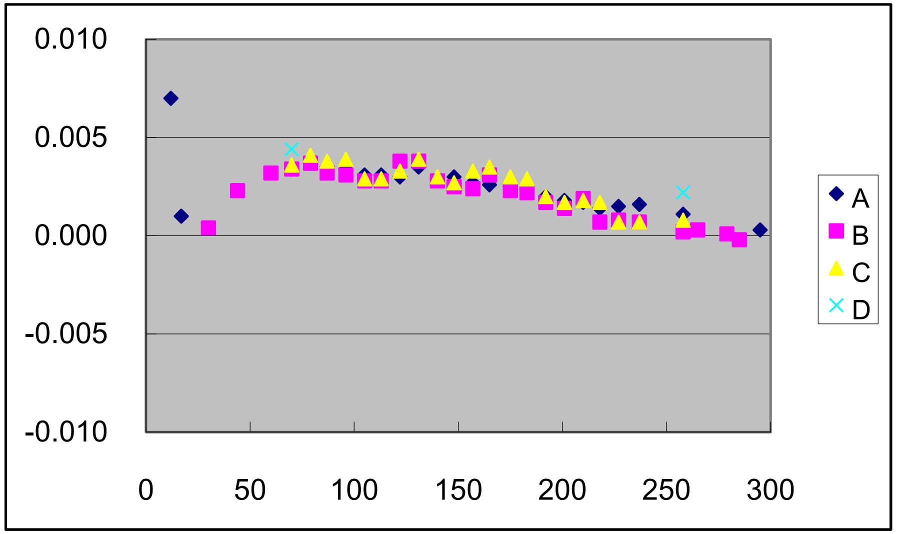
Depth of cell surface (a, b)



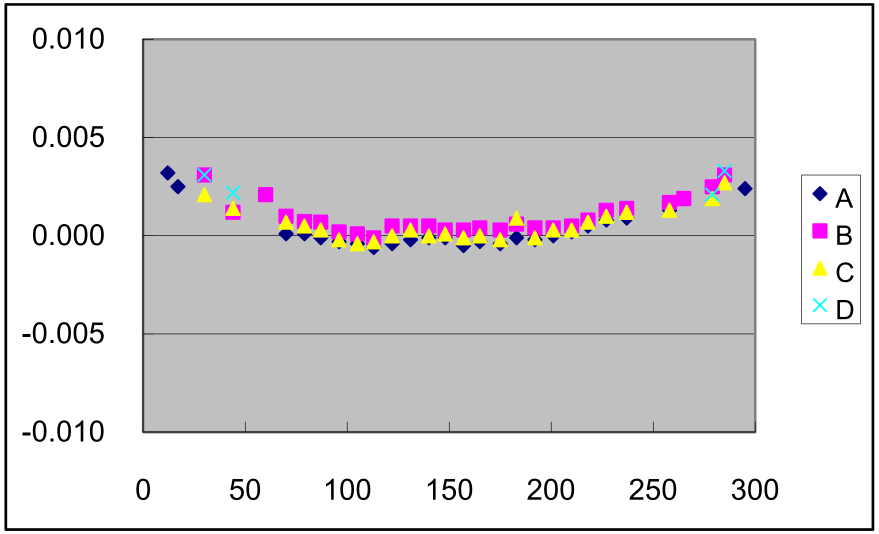
Reference surface flatness of Q1-1

First quadrant out of four of the first quadrant structure.

A-plane



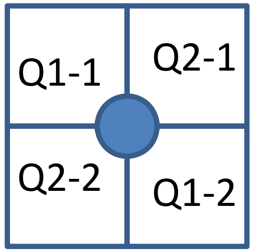
B-plane



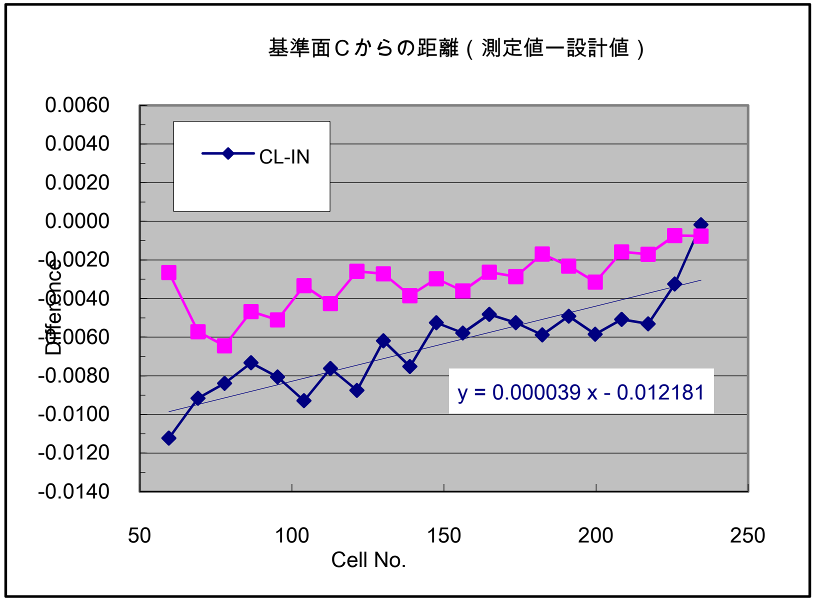
A Flatness: 4 μm
B Flatness: 4 μm, Perpendicularity w.r.t. A: 4 μm
C Perpendicularity w.r.t. A+B: ?? μm

This measurement was performed by vendor and confirmed by KEK.

Q1-1 and Q1-2

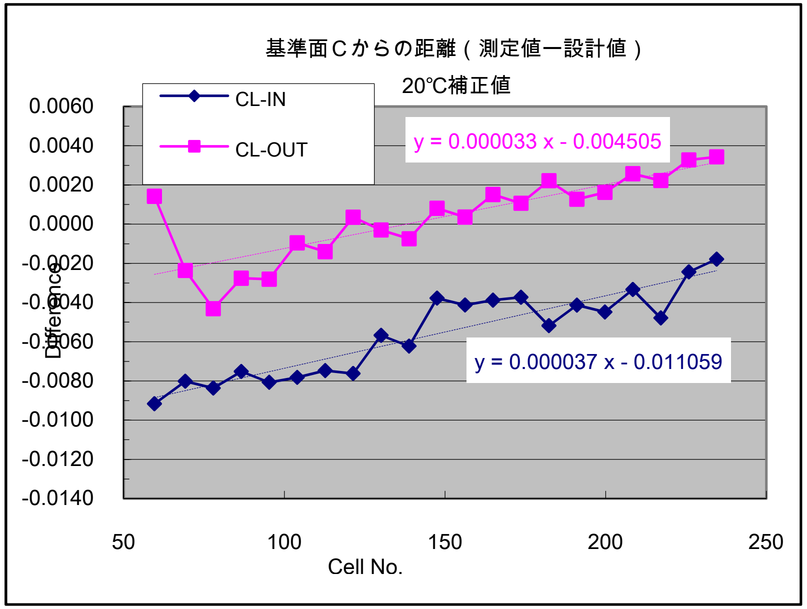


Q1-1



Slope = 3-4 X 10^{-5}

Q1-2

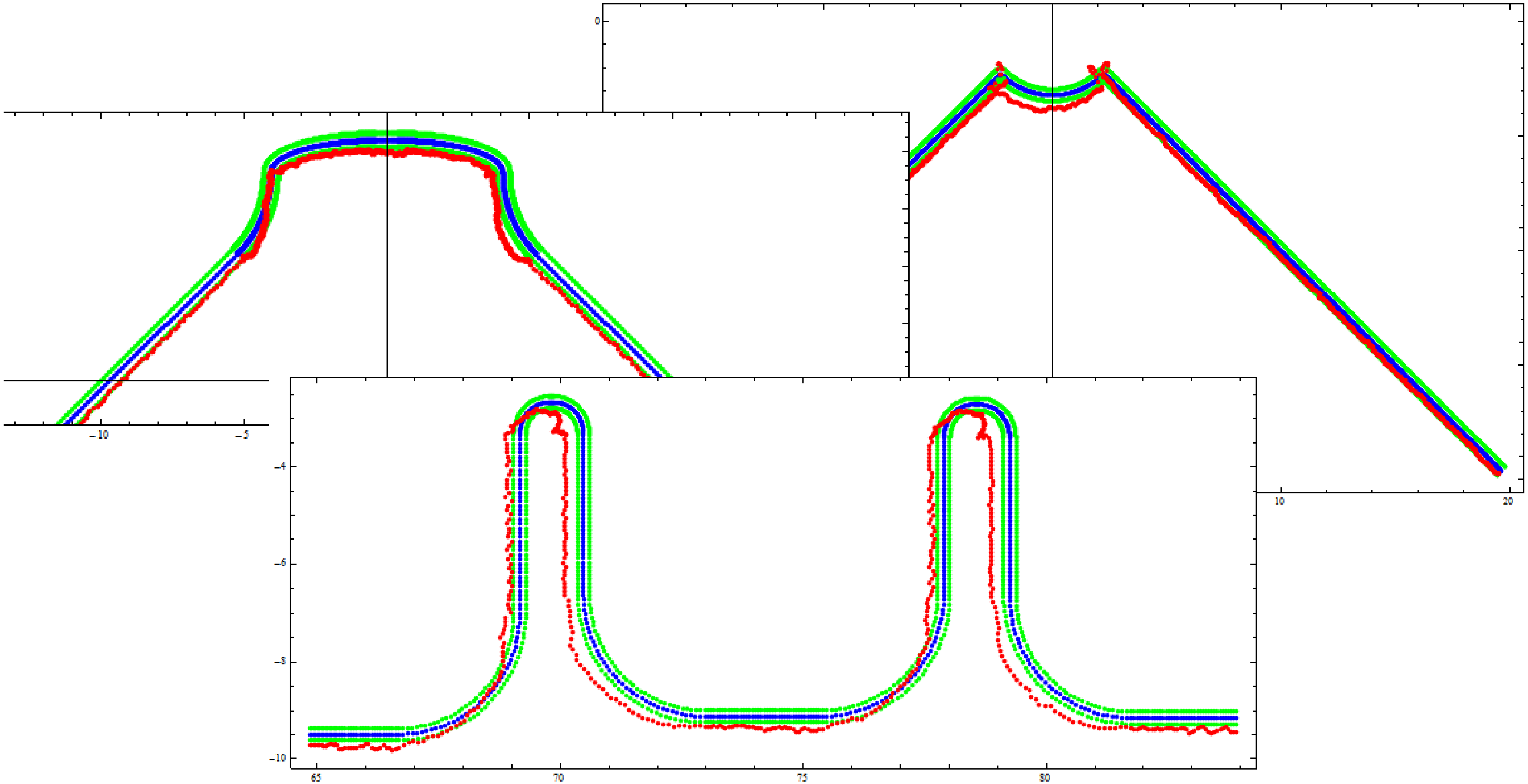


Slope = 3-4 X 10^{-5}

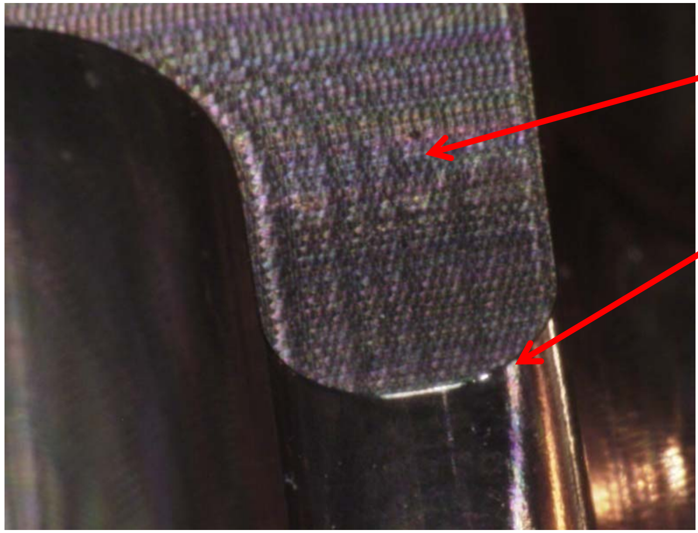
Positive slope appears consistently. Machining was confirmed stable!
Slope = 3~4 X 10^{-5} level, making more than several microns in 200mm.
However, the 3D cutting proceeds from an end to the other end continuously so that the connection between surfaces seems OK.

Profile of quadrant Q1-1

Measured w.r.t. A-B-C reference planes. Green lines are ±2.5 microns.
Followings shows worst part out of four measured areas along the axis.



Milled surface optical view

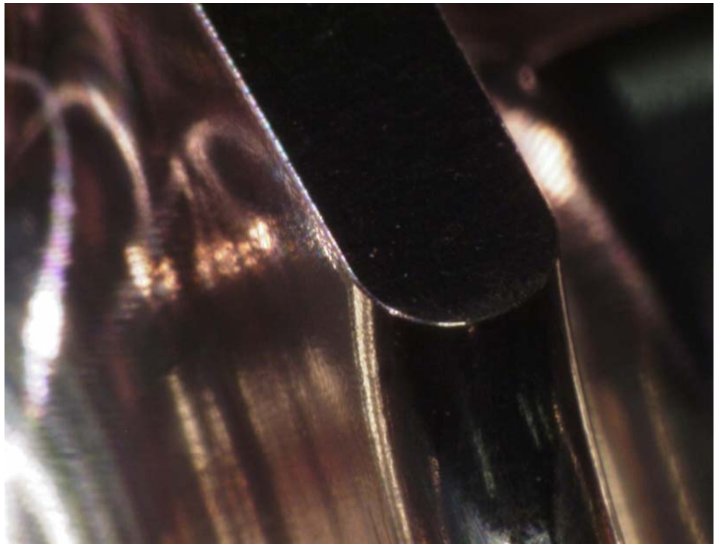


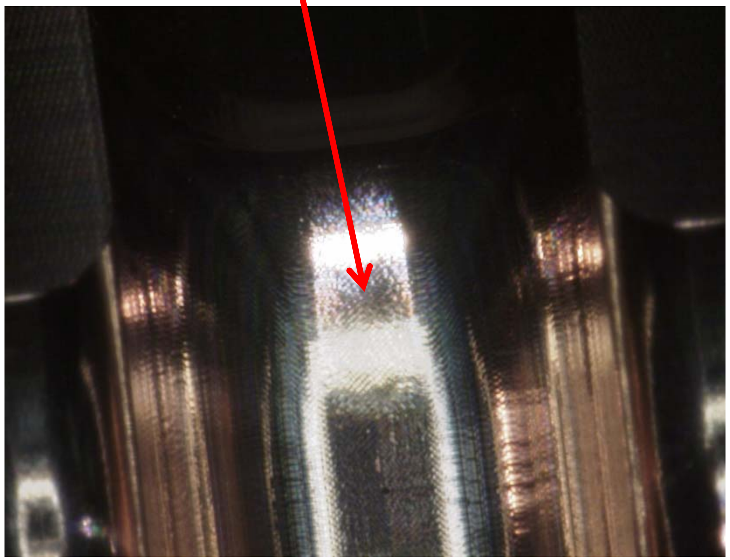
Reference plane formation by milling

50 micron rounding

Cavity wall formation

....





Dimple tuning consideration

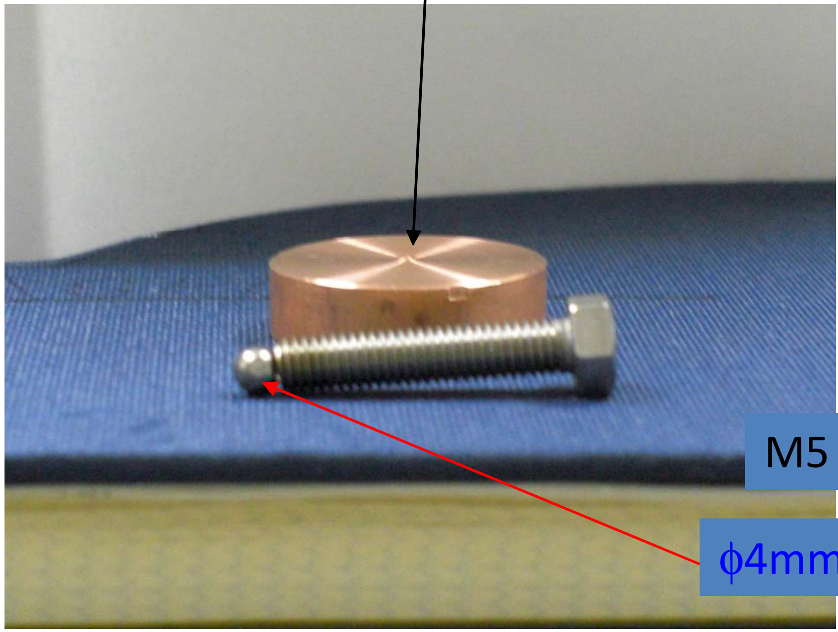
- Cavity sensitivity by Riccardo
  - df/db= - 1MHz/micron
  - df/da= + 0.24MHz/micron
  - d f /dgap (gap between quads) = + 0.37MHz/micron
- Tuning sensitivity
  - Riccardo: +10MHz/0.3mm-push, -10MHz/0.4mm-push-back
  - Higo: cone, height h, base r=4.2/2:
    - df/dh= + 12MHz/mm
- Tuning amount
  - Riccardo requirement form RF match: ±5MHz
  - Vendor potential ~±5μm→±5MHz
  - Required tuning amount <±10MHz → 0.5mm/hole
    - Fab. at 20C and operation at 30C → - 2MHz
    - Temperature tuning capability ±10C → ±2MHz
- Dimpling
  - Push into cell by M5 screw: can be deformed in C150 (CuZr).
  - Push towards outerwards: not yet considered carefully.

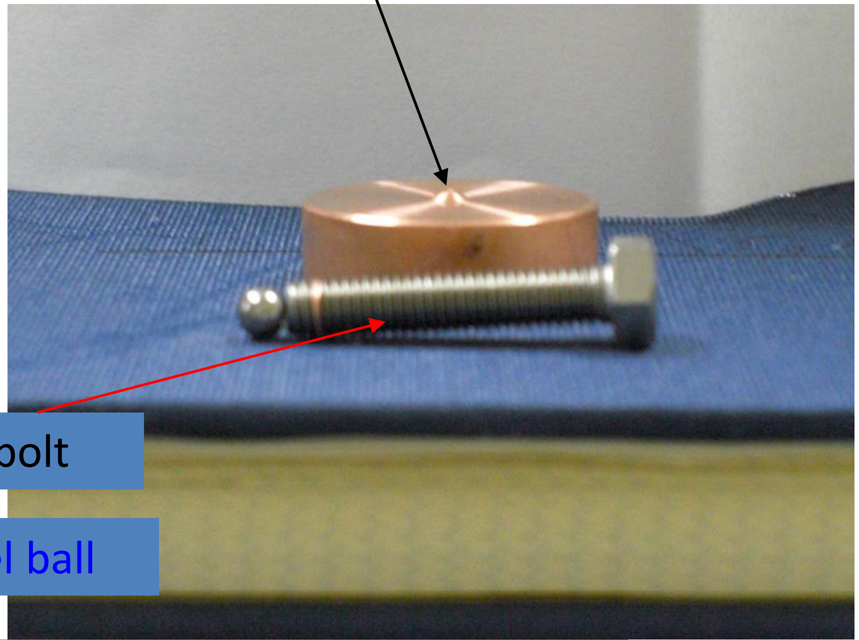
Rough test results of dimpling for rf tuning
081003 Y.Higashi

Dimpled height

0.43mm+/- 50μm

0.63mm+/- 50μm





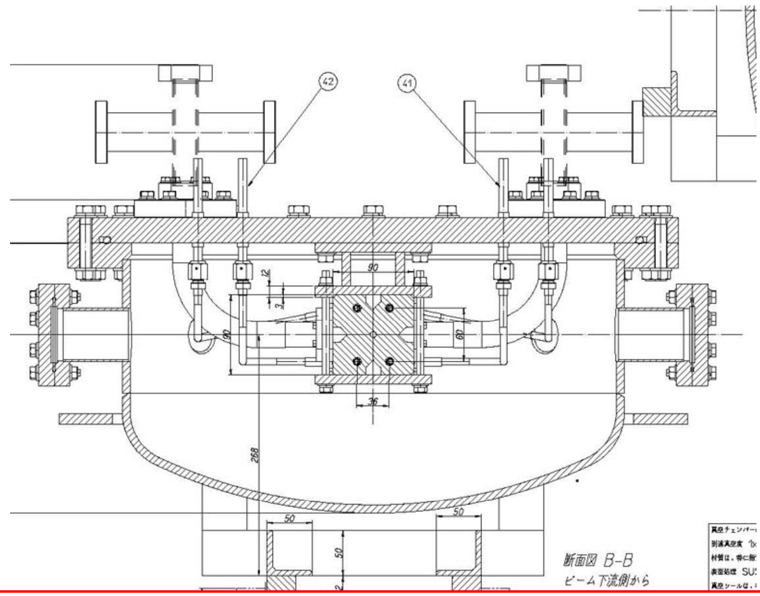
M5 SUS bolt

ϕ4mm steel ball

Not big torque was applied -> standard torque for M5 bolt

@ Deterioration of flatness, straightness and twist of structure due to dimple tuning should be considered.

Vacuum chamber preparation



- Quads are assembled and fixed to upper big flange.
- CF114 flange equipped with waveguide flange feature.
- Adjustment of electric phase and position might be difficult.
  - We introduce bellows for CF114 to be position-adjusted?
  - Gaskets with different thicknesses are prepared for adjustment.
- VCR connector for copper cooling tube with EBW to quad body.
- Vacuum sealing by U-tight seal, similar to helicoflex but cheap.
- Chamber is EP finish. Baking or not??

Quad installation into vacuum chamber

- May be over spec. but we do not know how much we need.
  - We design as we can do it.
- Some features are the following.
  - Material is C150 (CuZr) without annealing at all.
  - Quads may only be surface treated by organic rinsing solution.
  - Adjustable mechanism between quad and Nextef waveguide system.
  - Metal gasket seal for the chamber flanges.
  - Cooling water pipes are electron beam welded on each quad.

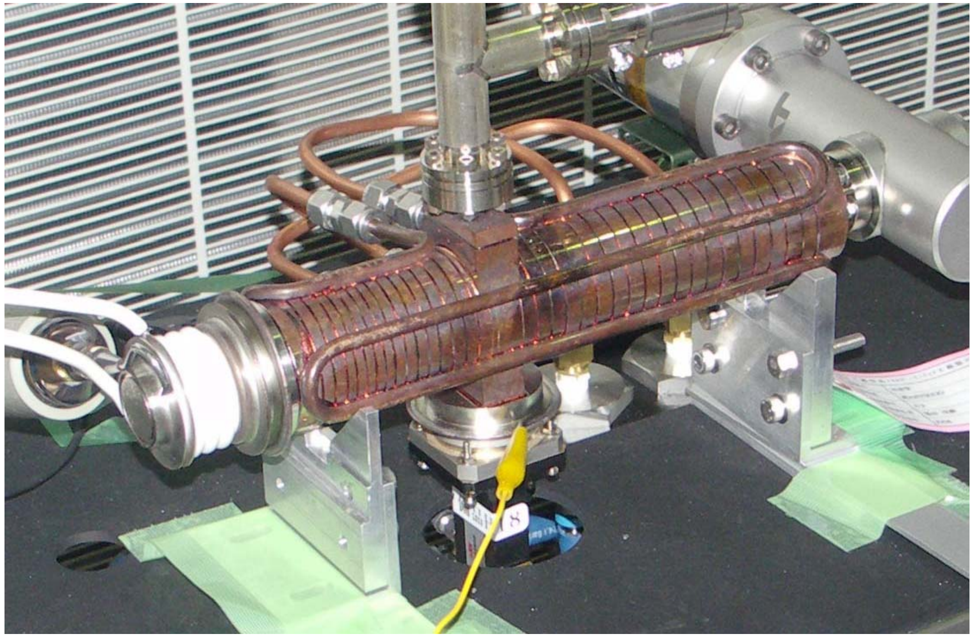
Assembly in next January

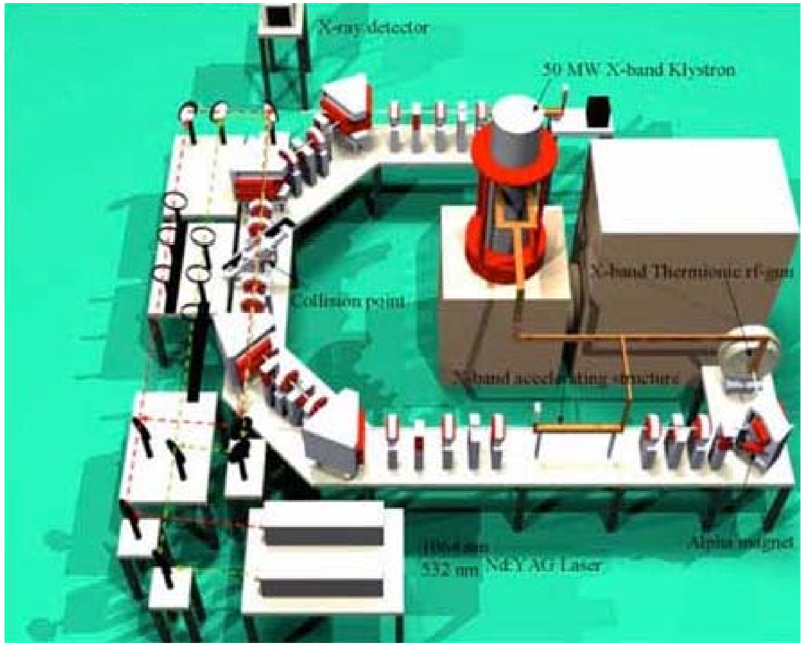
1. Assemble four quadrants
2. Check alignment
3. RF check with bead pull (trying to import SLAC program for better tuning)
4. Tuning as needed
5. Copper tube EBW
6. Surface rinsing
7. Assemble on the top flange
8. Vacuum check
9. Move to Nextef
10. Connect to Nextef with N_2 gas purge

Structure fabrication summary

- Disk-undamp fabrication #3, #4 in progress at SLAC.
- Disk-damp test cell inspected. Some improvement was confirmed and now in final production stage. Shipping to SLAC will be next year.
- Quad actual fabrication is in progress. Vacuum chamber fabrication by the end of this year.

Collaboration with Univ. of Tokyo





Fabrication of 1MeV accelerator for NDT.

Application of LC technology to Compton scattered X-ray source development.
PPM klystron, acc structure, RF gun, loads, etc.

Now, we are fairly lightly involved as long as any vision for us becomes clear.
We are presently focusing to CLIC-based studies.

Conclusion

- High power test
  - Started high power test facility Nextef.
  - Started processing T18_vg2.4_Disk #2.
  - Pulse compression is realized in 2009.
  - Another test station will be realized.
- Structure fabrications
  - Disk-damp, quads are under fabrication.
  - C10, CD10 will follow.
- Basic researches
  - Narrow waveguide high gradient test.
  - Preparing samples to SLAC for pulse heating and single-cell study at SLAC.
  - Similar experiments are in consideration to be performed at KEK.
- Moderate activity with Univ. of Tokyo
  - Application of LC-based X-band technology into
  - Compact NDT
  - Compton scattered X-ray source

Thank you for the UK effort on everything, including request of paper submission!

We congratulate the successful startup of X-band collaboration from Wales to the world.