High Frequency High Field Studies at KEK

Shuji Matsumoto

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Contents

- Review on X band researches at KEK as a derivative of LC R&D.
- On-going and Future X band programs.

List of the peoples participate in this research

Toshiyasu Higo, Shigeki Fukuda,
Shuji Matsumoto, Mitsuo Akemoto,
Noboru Kudoh, Kazue Yokoyama,
Takuya Kamitani, Mitsuhiro Yoshida
Accelerator Laboratory, KEK

Yasuo Higashi, Toshikazu Takatomi,
Kenji Ueno
Mechanical Engineering Center, KEK

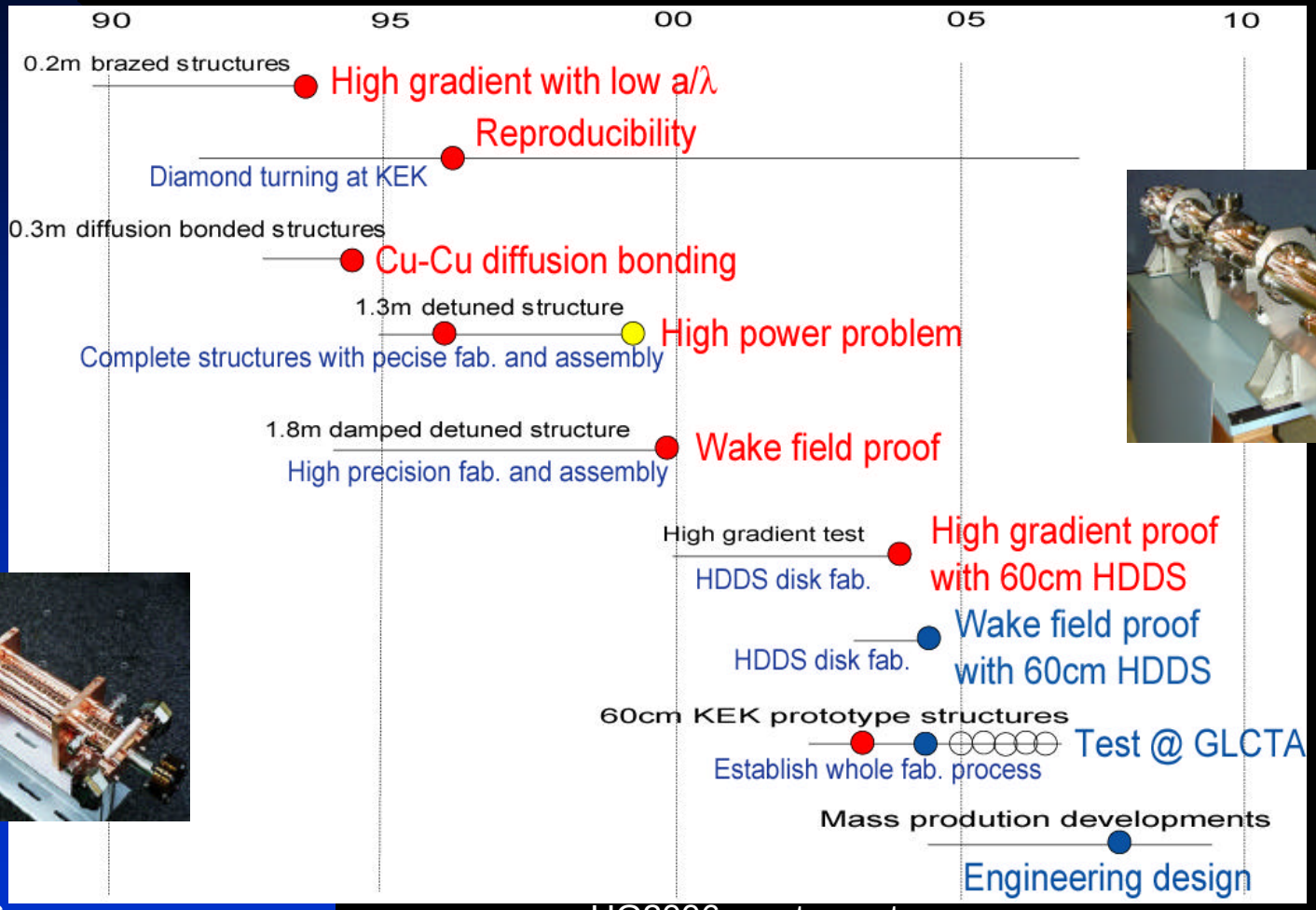
Review of X-band* Research at KEK as of today

* 11.424GHz, 4 x 2856MHz

- Accelerator Structure
  - Latest prototype KX03 has been fabricated, assembled. The test is almost finished.
- Klystron
  - PPM6 test is ongoing.
- Modulator
  - 2 Line-type modulators built and run.
- RF Components
  - RF Load etc.

Accelerator Structure Development

- Key technologies are in hand



RDDS1

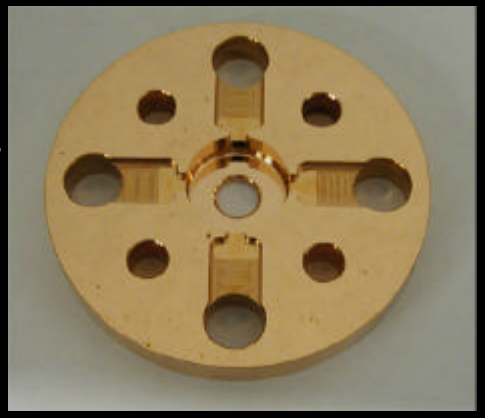
KX01

T.Higo

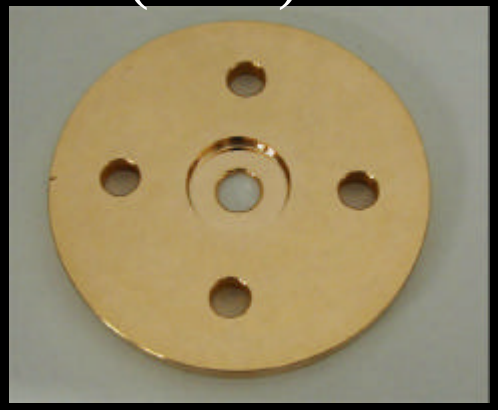
Disk Shape Evolution

The method of ultra-fine machining has been established.

HDS(1992)

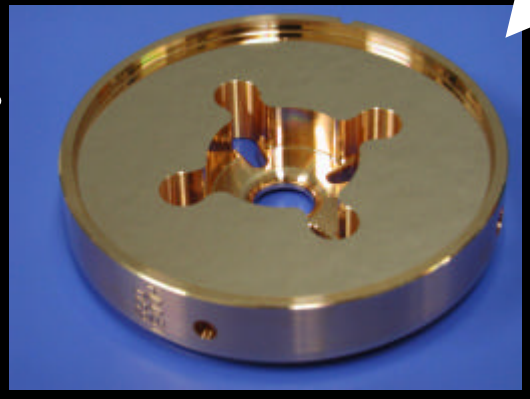


DS(1996)

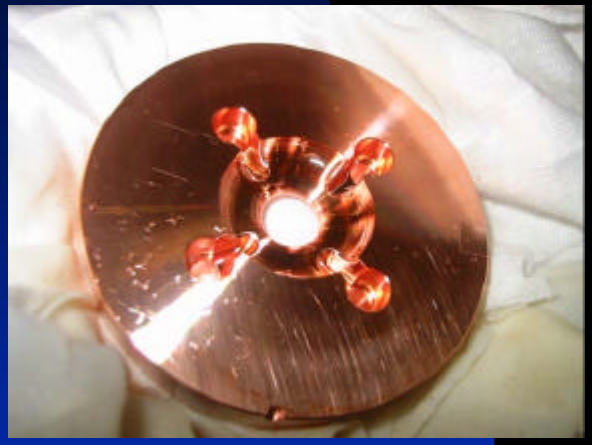


RDDS(1999)

HDDS(2003)



RTOP-HDDS (2004)



KEK Mechanical Engineering Center

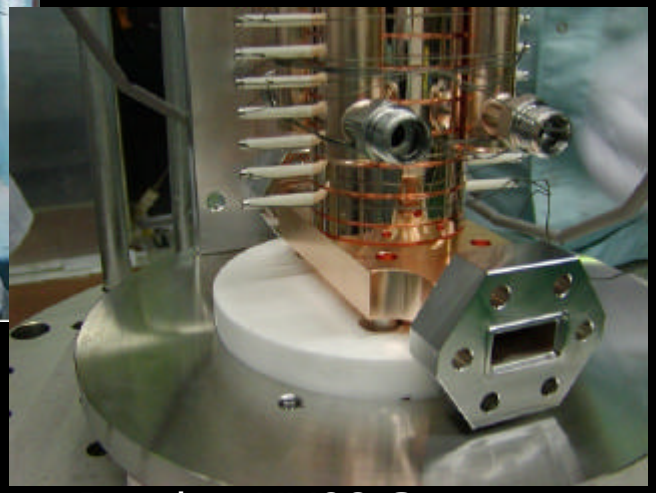
Y.Higashi, T.Higo

Fine Machining and Hydrogen Furnace

KEK Mechanical Engineering Center

The Ultra-fine lathe machine

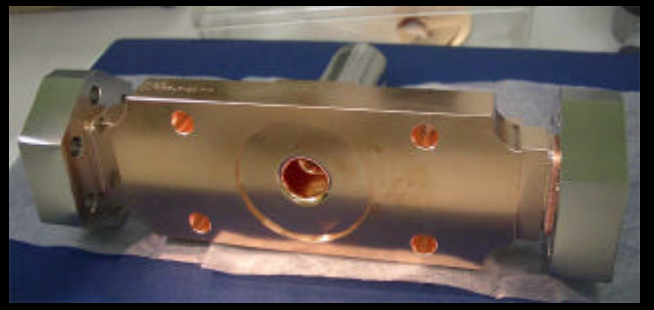
KEK Hydrogen Furnace
Enable to assemble a short accelerating structure



Brazing KX02 Structure (2005)

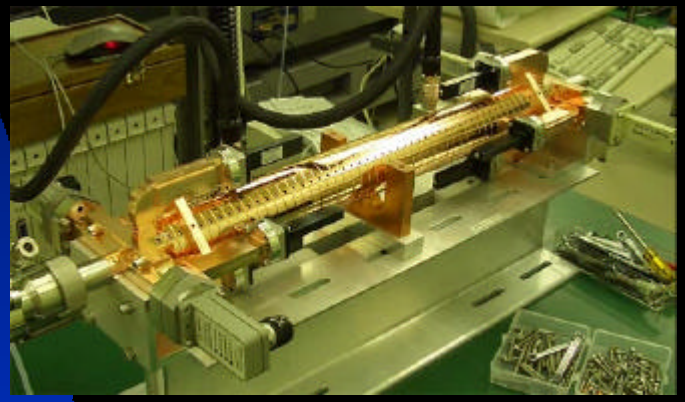
KX03 fabrication (2005)

HDDS cell with HOM extraction

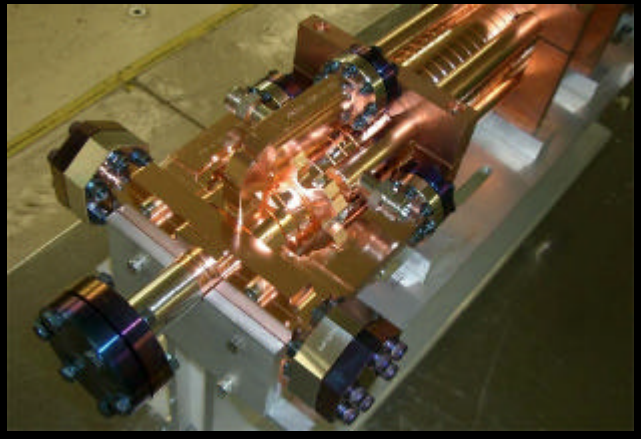


WG type coupler

HOM meas. before bake



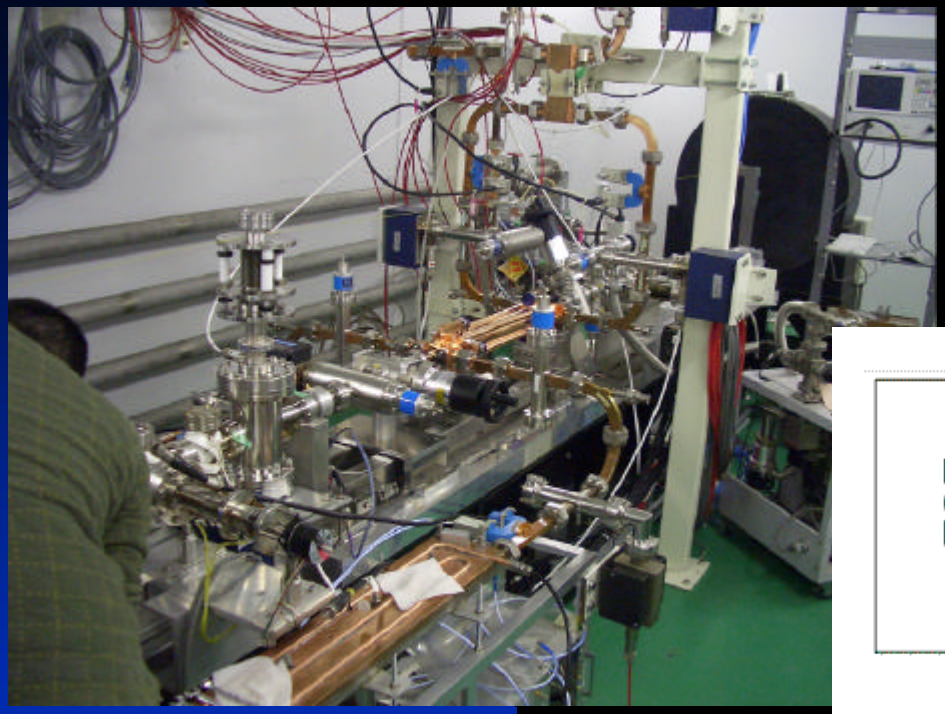
Completion after bake



Final as linear collider spec

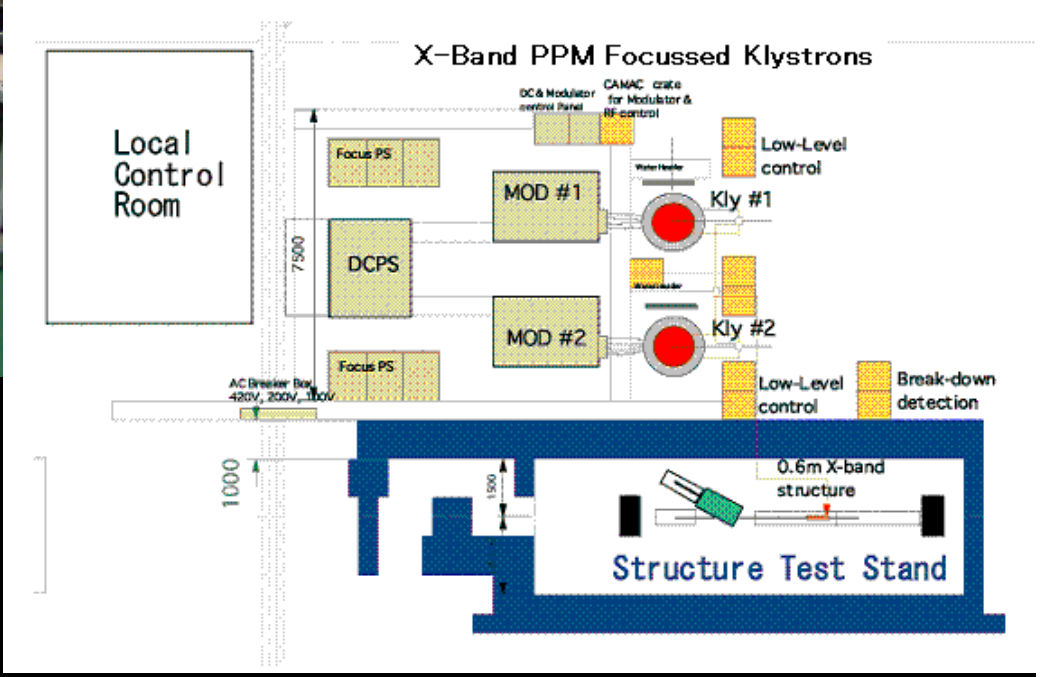
High field studies at KEK XTF* (since 2003)

*formerly built as “GLCTA” for X band LC R&D in 2003.

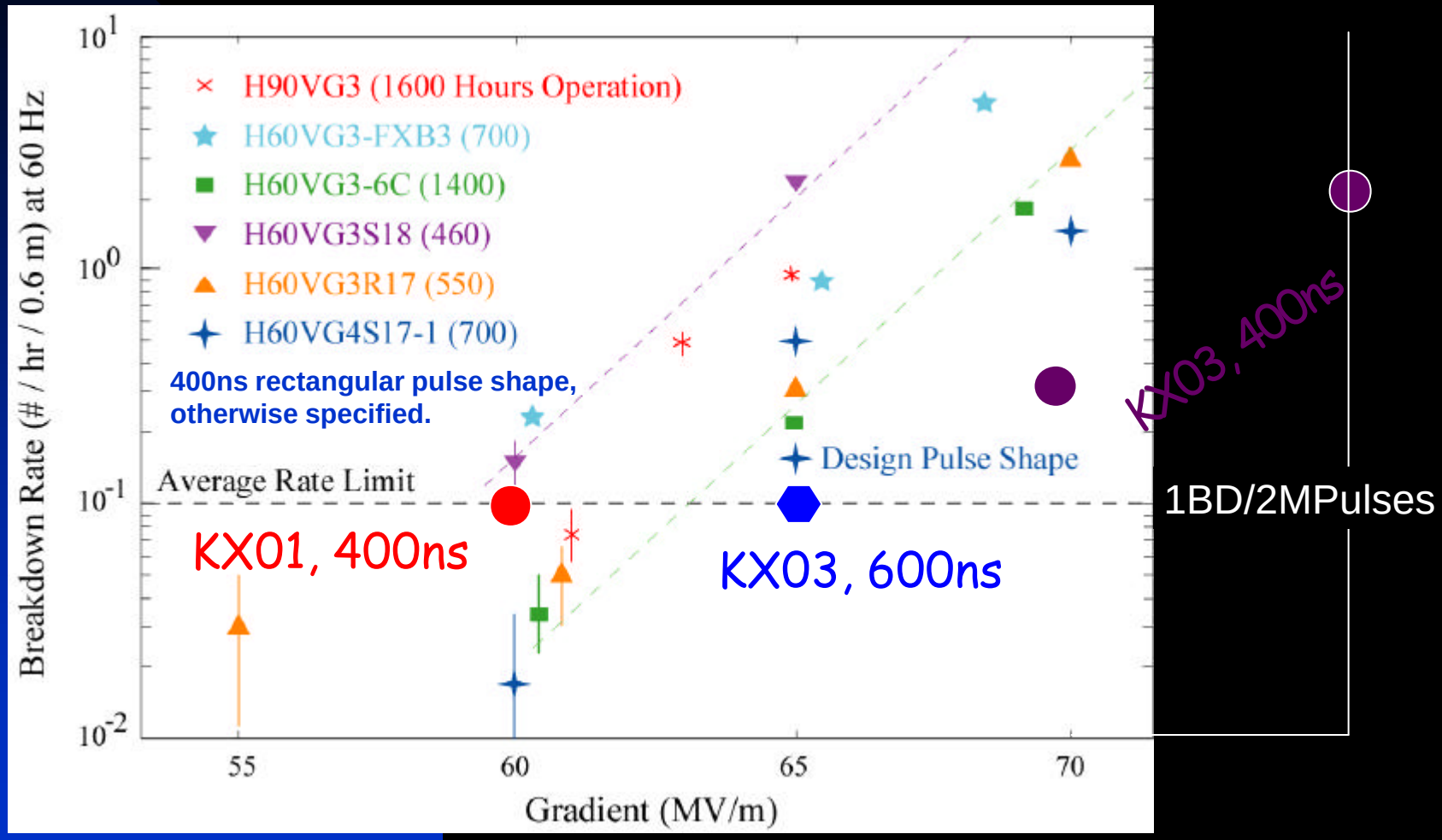


Inside the shield room

Plan view of XTF



Breakdown Rate meets the LC requirement.



Summary on Accelerator Structure Study

- The technology to build a 60cm class structure is established.
- LC Spec, “BD rate should be <1BD/hr, 2M pulses at 65MV/m”, has been achieved.
  - Need more R&D to get more gradient
- Excellent stability at 60MV/m confirmed.
  - Investigate possible application.

X Band PPM Klystron Research at KEK

- So far 6 prototype tubes have been built.
- Some meets LC requirement in power and RF pulse width (75MW,1.6μs).
- Limited work is ongoing after 2004 to obtain a stable tube with 50MW output power.

(KEK-Toshiba)X-band PPM Klystron

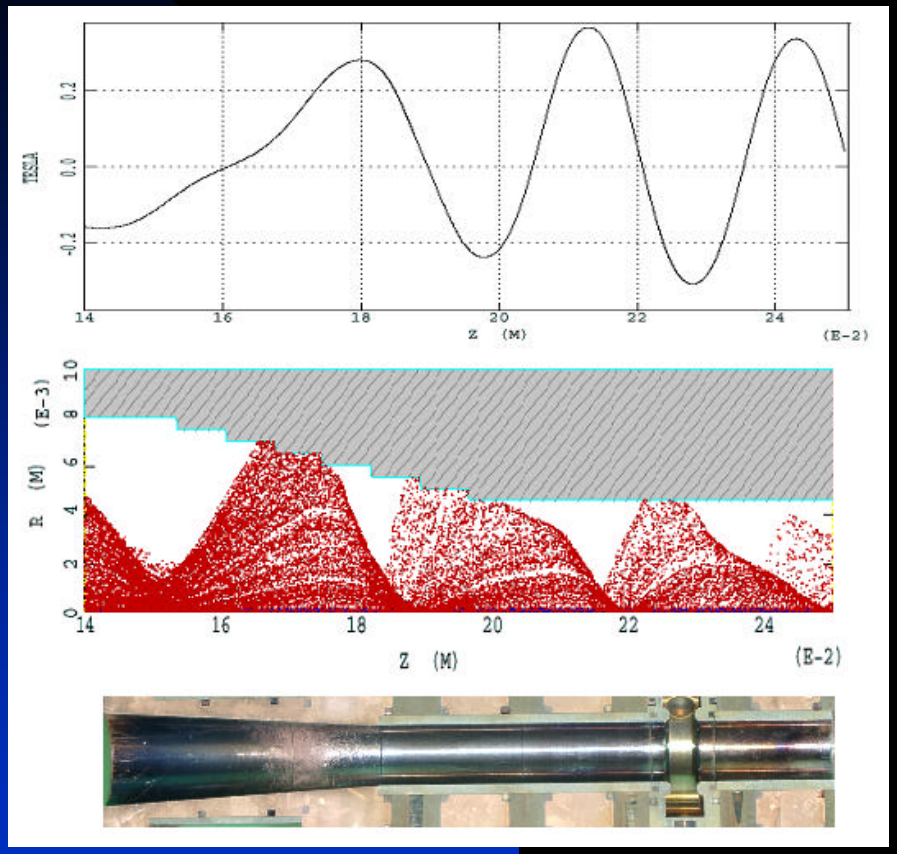
PPM4A (2003)

Frequency	11.424GHz
Peak Power	75MW
Pulse width	1.6μs
Repetition	150Hz
Cathode Voltage	480kV
Cathode Current	266A
Perveance	0.8uK
Efficiency	>55%
Main Focus	PPM
Max B / period	0.32T / 30mm
Magnet Material	NdFeB

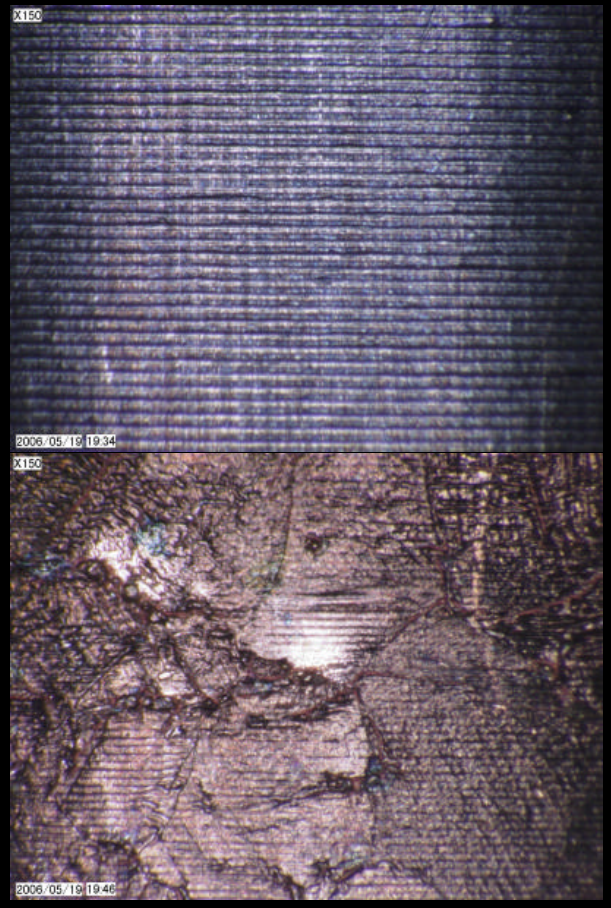
Recent Topic of PPM klystron Research

- Damage on Beam pipe surface due to stopband beam loss
- Damage found in Collector

Stopband Beam Loss Damage



Mag Field, Beam trajectory at 150kV,
Damage on the beam pipe.



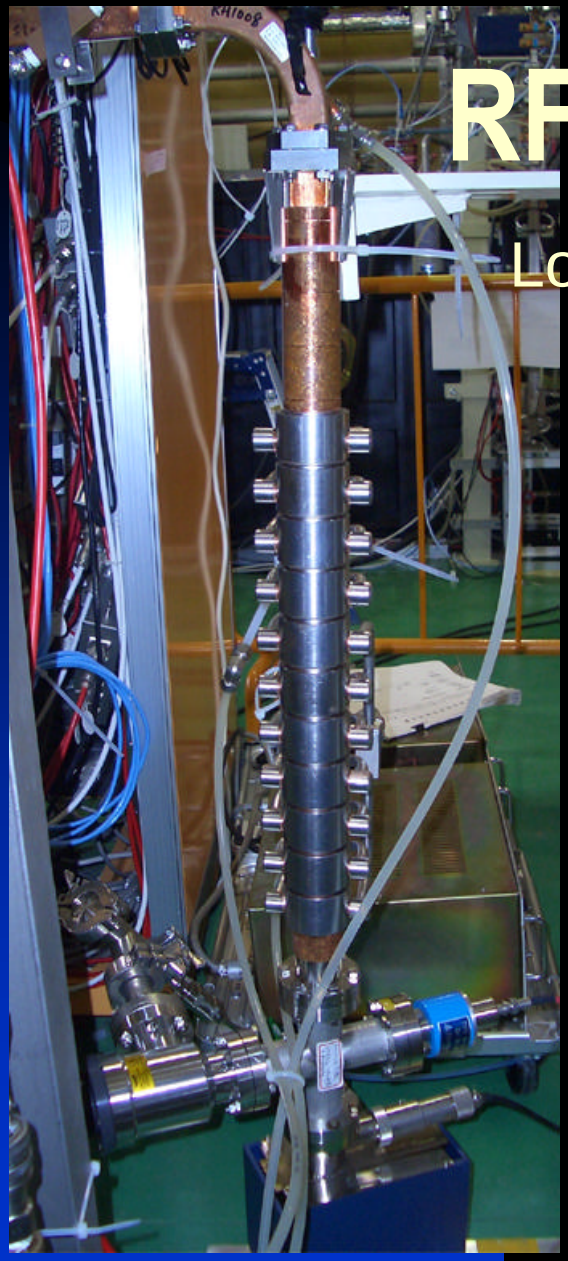
Microscope images of the Cu beampipe surface (x150)
Loss Free Area(top)/ Damaged Area(bottom)

XTF Modulator

2 modulators built in 2003-2004, #3 and #4. They are line-type modulator with inverter chargers.

#3 meets completely LC spec. It has two identical and independent PFNs to drive 2 PPM klystrons @150Hz.
#3 will be transferred to KEKB Injector Test Hall.

While #4 has one PFN and drives a single klystron.
#4 sits at Injector Hall and runs X band klystron test stand already.



RF Components

Lower Field RF Load: Design and Fabrication

A.Lunin, T.Higo, K.Kudoh

On-going and Future X band programs

- Application (for compact accelerators, X-ray source)
- Fundamental research utilizes XTF.

X-Band Technology Application

① Tokyo Univ. （Collaboration work Ongoing）

X-band Accelerator＋Compton X-ray

② Energy Compressor in Injector LINAC (under investigation）

KEKB, PF

③ Compact Electron Accelerator (Collaboration)

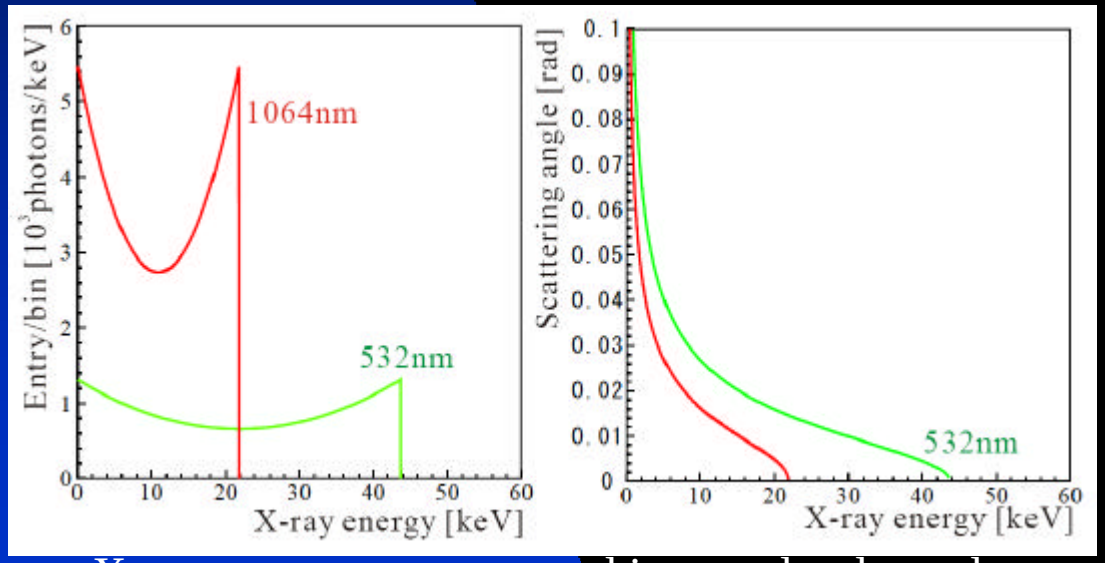
9.4GHz NDT （Ongoing）

Medical accelerator for cancer therapy (Planned）

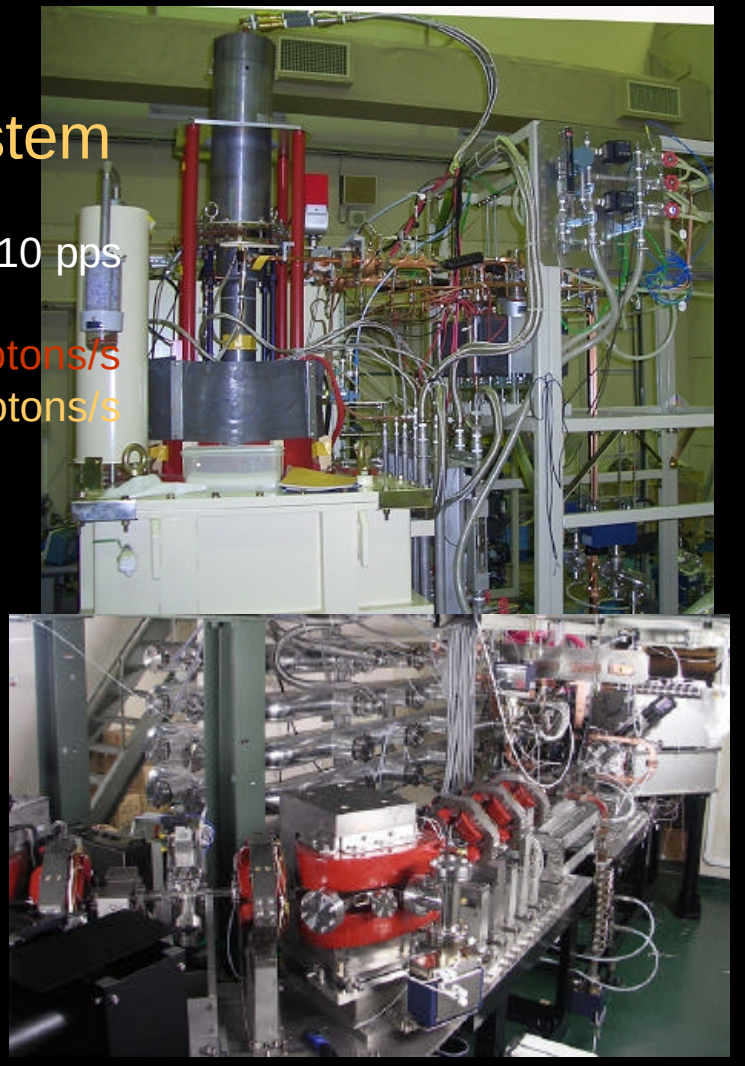
Compton scattered X-ray source for medical use studied at Tokyo Univ. at Tokai

Collaboration: X-Band Accelerator system

E beam: 30 MeV, 20 pC/bunch, 10^4 bunches/RF pulse, 10 pps
Laser: Q-switch Nd:YAG
X-ray : 1064 nm, 2.5 J, 10 pps 21.9 keV, 1.7×10^9 photons/s
532 nm, 1.4 J, 10 pps 42.9 keV, 1.0×10^9 photons/s



X-ray energy spectrum and its angular dependence



2 X-band application to KEKB injector linac

- A large energy spread of the positron beam is due to a position dependence of the energy gain.

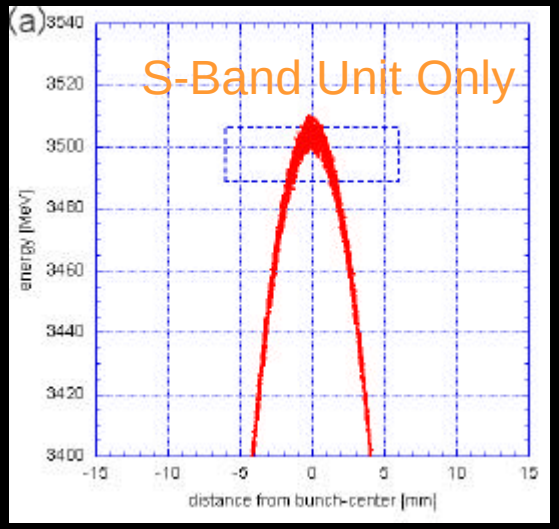
$$E_{total\,gain} = E_{e^+}\cos(2p\frac{z}{l_s}) \approx E_{e^+}\left\{1-\frac{1}{2}(2p\frac{z}{l_s})^2\right\}$$

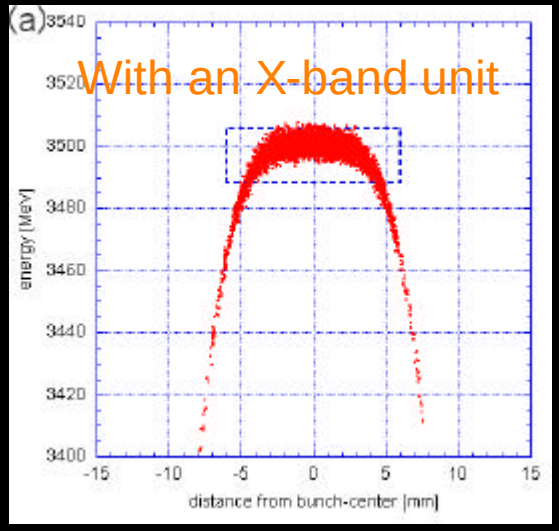
- To suppress the energy spread, the energy equalization utilizes the superimposed acceleration of the S-band and X-band modules.

$$E_{equalizer} = \Delta E\cos(2p\frac{z}{l_s}) - \Delta E\cos(2p\frac{z}{l_x})$$

$$\approx \Delta E \times \frac{1}{2}(2p\frac{z}{l_s})^2(4^2-1)$$

- It can be achieved with one unit of X-band (~200 MeV) for positron beam energy of 3500MeV.

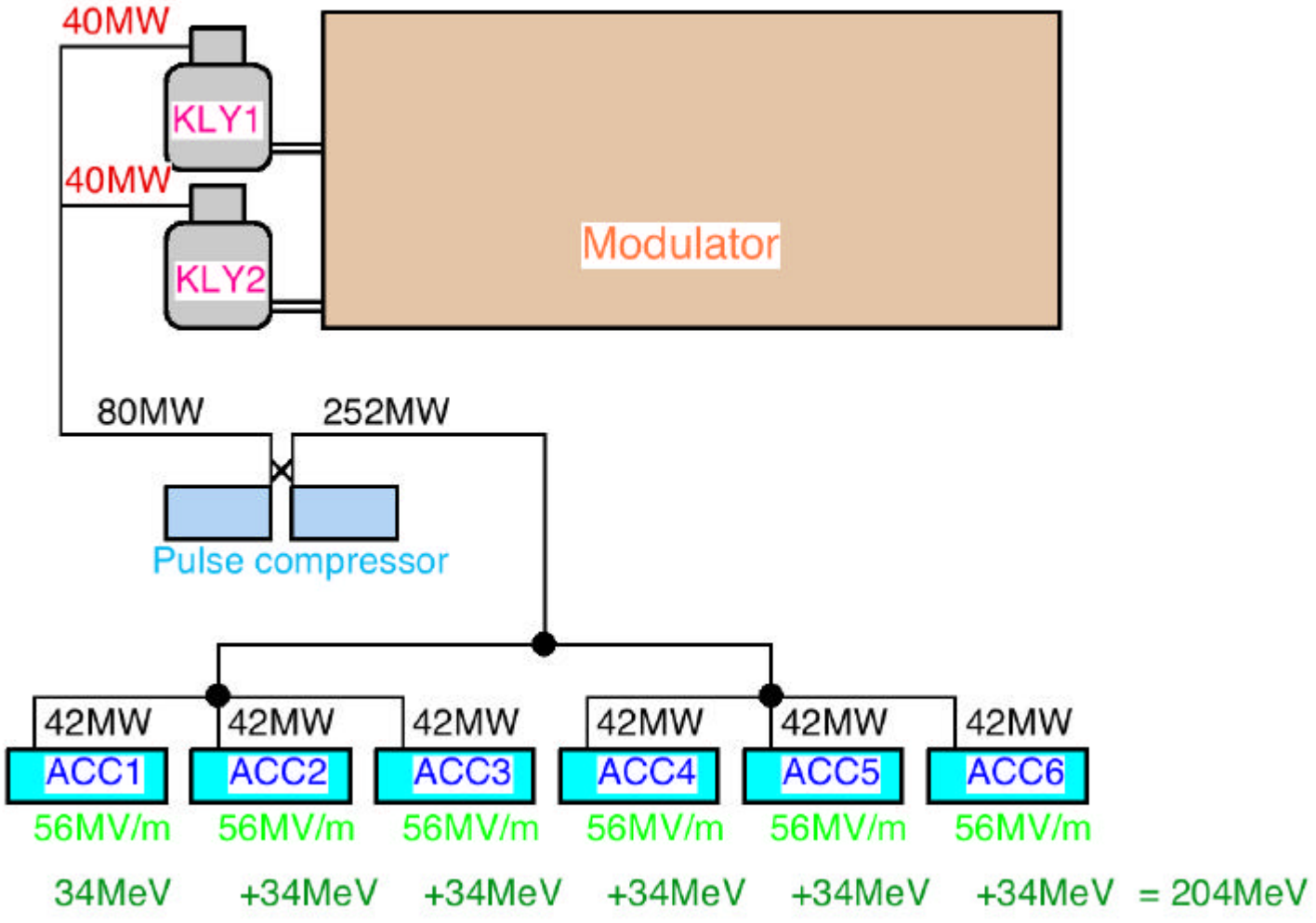




Energy distribution at the end of the linac

T.Kamitani, K.Yokoyama

2 X-band accelerator unit



T.Kamitani, K.Yokoyama

One X-band RF source and a few accelerating sections have already been developed at KEK.

Challenge to the Multi-Beam Klystron (Proposal)

- There are various needs for MBK and **we are trying to develop this technology**
- (Needs) **L-band super MBK for ILC**

  Low voltage, high power (10MW) and high efficiency

  C-band driver klystron for Super KEKB

  Compact, low voltage small klystron

  X-band MBK for medical application

  Low voltage, high power(10-20MW) and compact

  →Technically very difficult

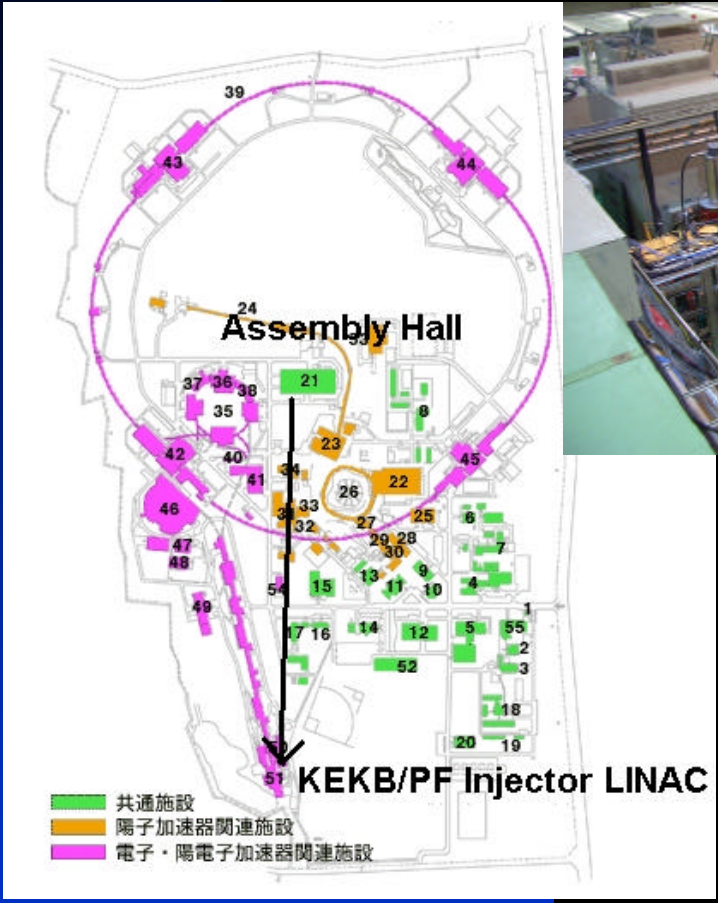
Future possibility →*higher frequency such as K to Ku band (20-30GHz)*

Fundamental Research on High Frequency and High Field RF

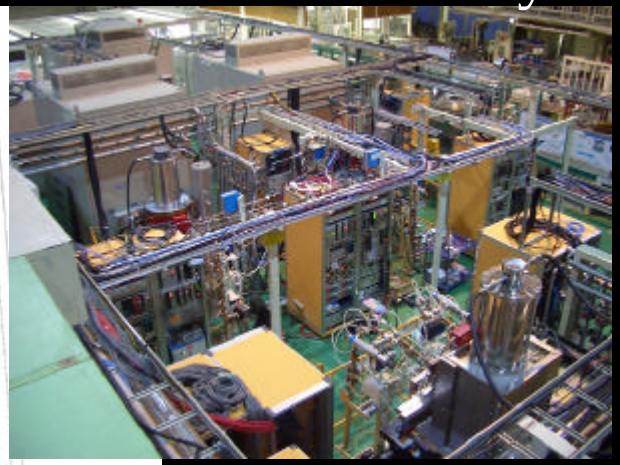
1. XTF moves to KEK Injector Hall
2. High Field test against (specifically made) waveguides
3. Single Cell Test @SLAC
4. Examination of various material using EBW machine
5. Collaboration

1. XTF Moving to LINAC

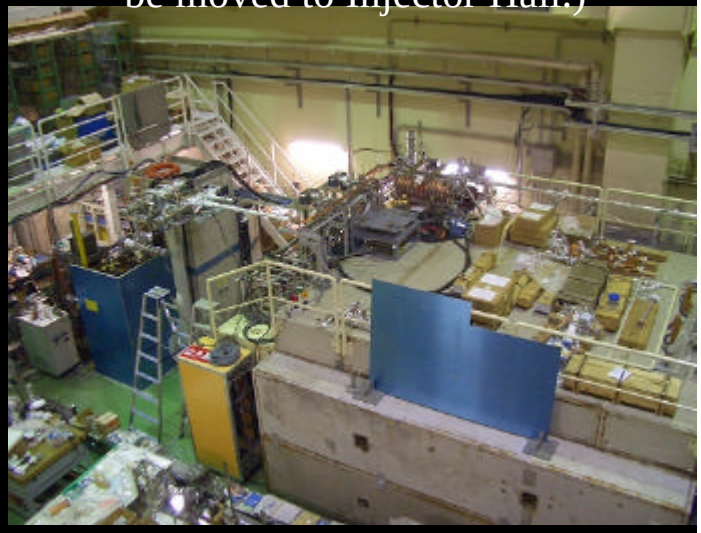
Plan view of KEK



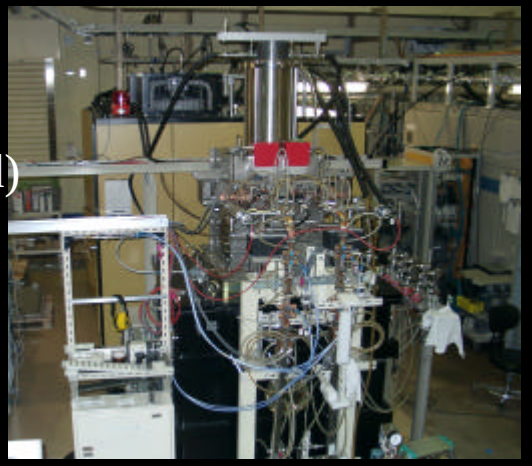
XTF in AH today



Structure Test (will be moved to Injector Hall.)



Klystron Test
(has already moved)

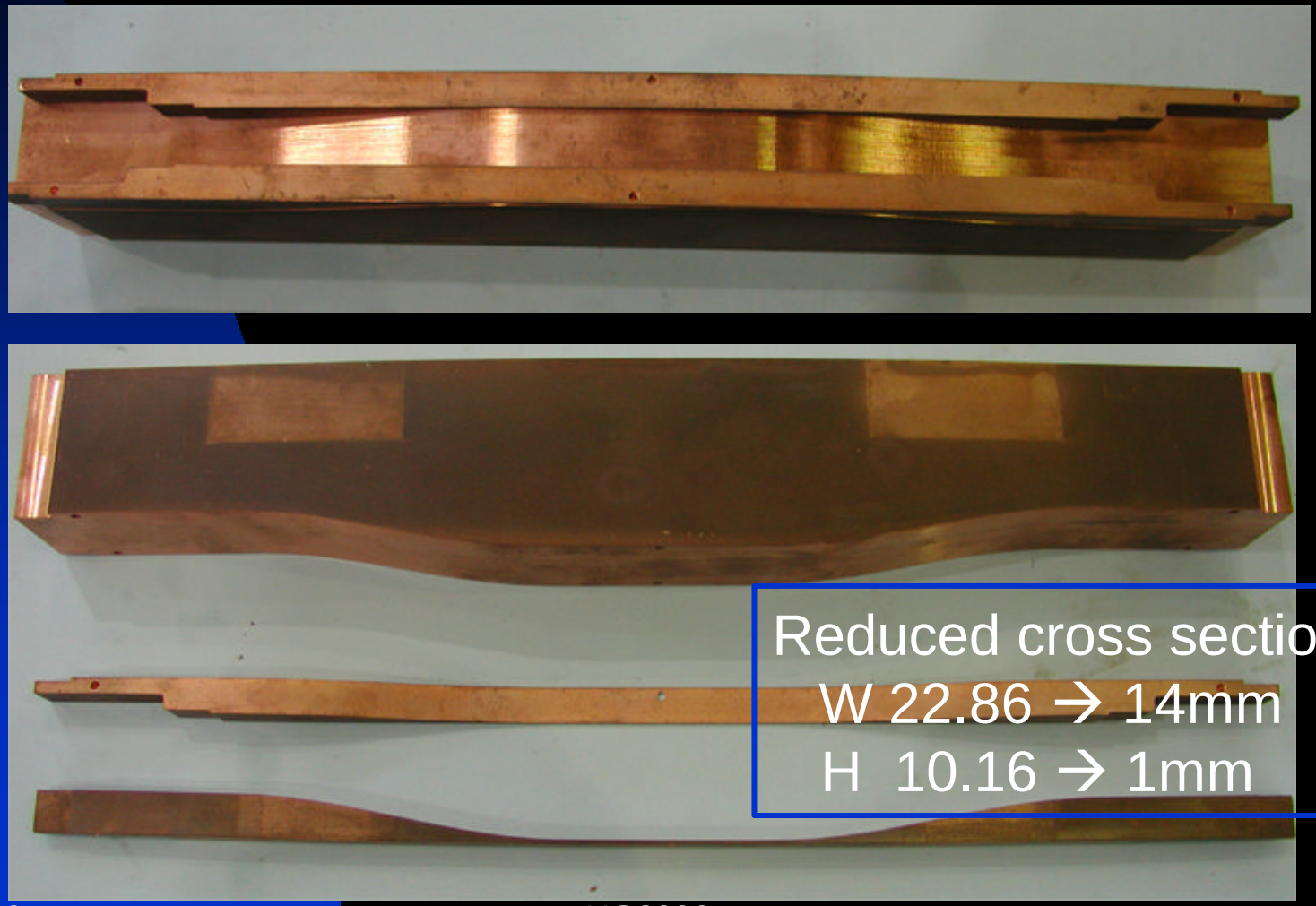


This moving project makes X-band activity integrate with those of S- and C-Band in KEK.

2.

Waveguide Parts under fabrication at KEK MEC

High Power Test will be done in this autumn.



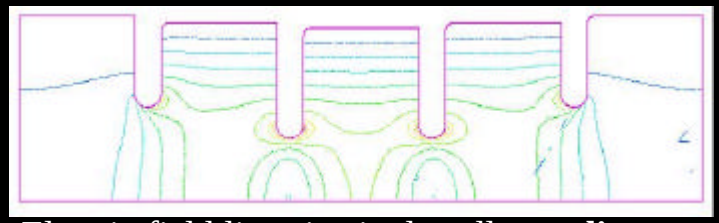
T.Higo, K.Yokoyama, N.Kudoh

3. Single cell traveling (TW) and standing wave (SW) structure 11.4 GHz high gradient study

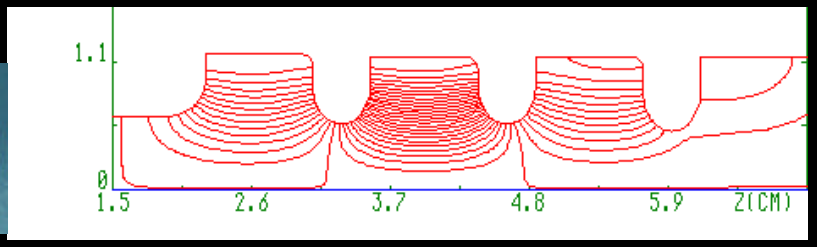
by Dolgashev

Goals:

- RF breakdown *vs.* circuit parameters (SW *vs.* TW)
- RF breakdown *vs.* different surface processing technique (etching, baking)
- RF breakdown *vs.* different materials: copper, molybdenum, molybdenum-copper



Electric field lines in single cell **traveling** wave structure



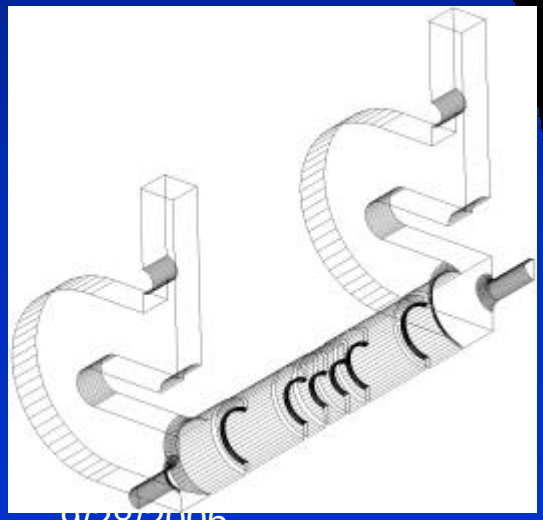
Electric field lines in single cell **standing** wave structure

TW SW copper structures

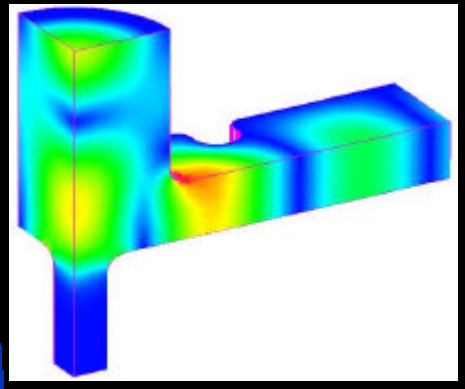
TW SW molybdenum structures

SW moly

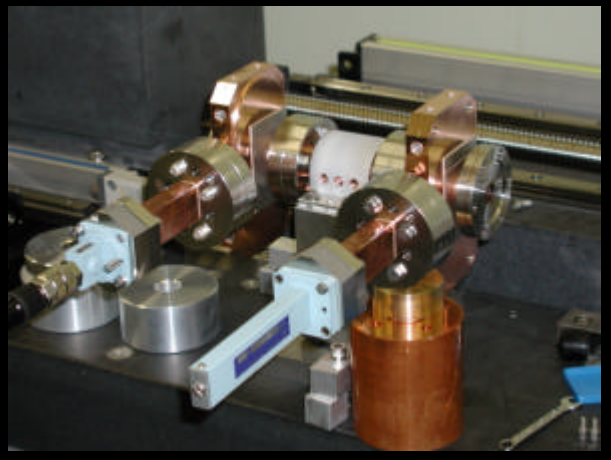
TW moly-copper cells



Single cell TW structure with mode-launchers



Surface electric fields in the final mode launcher E max.= 49 MV/m for 100 MW

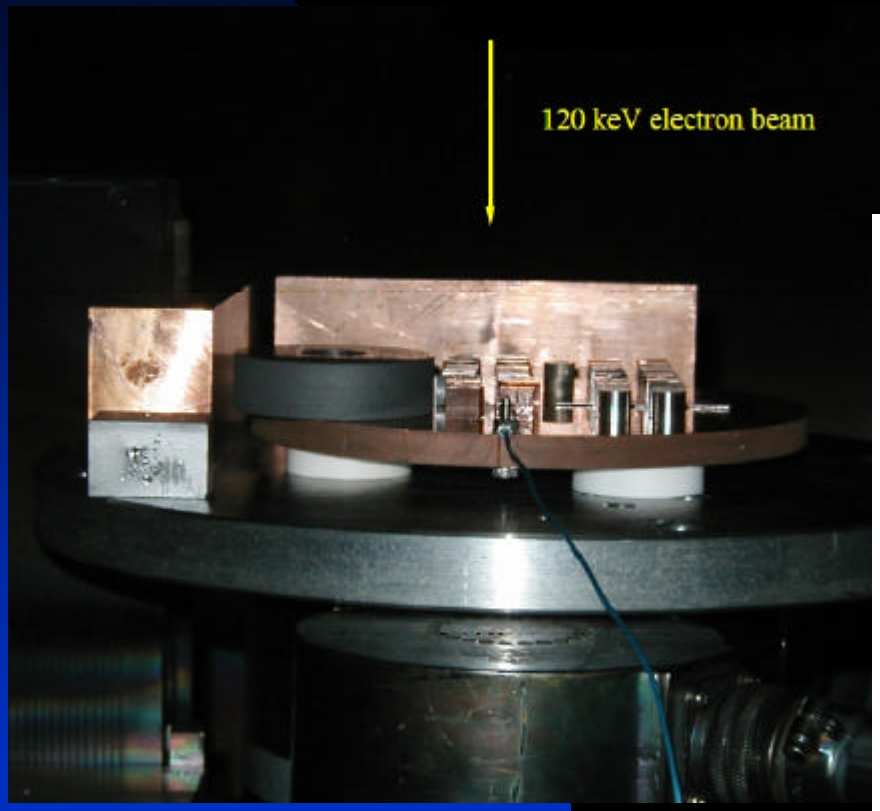


Bead-pull measurements of single cell TW structure

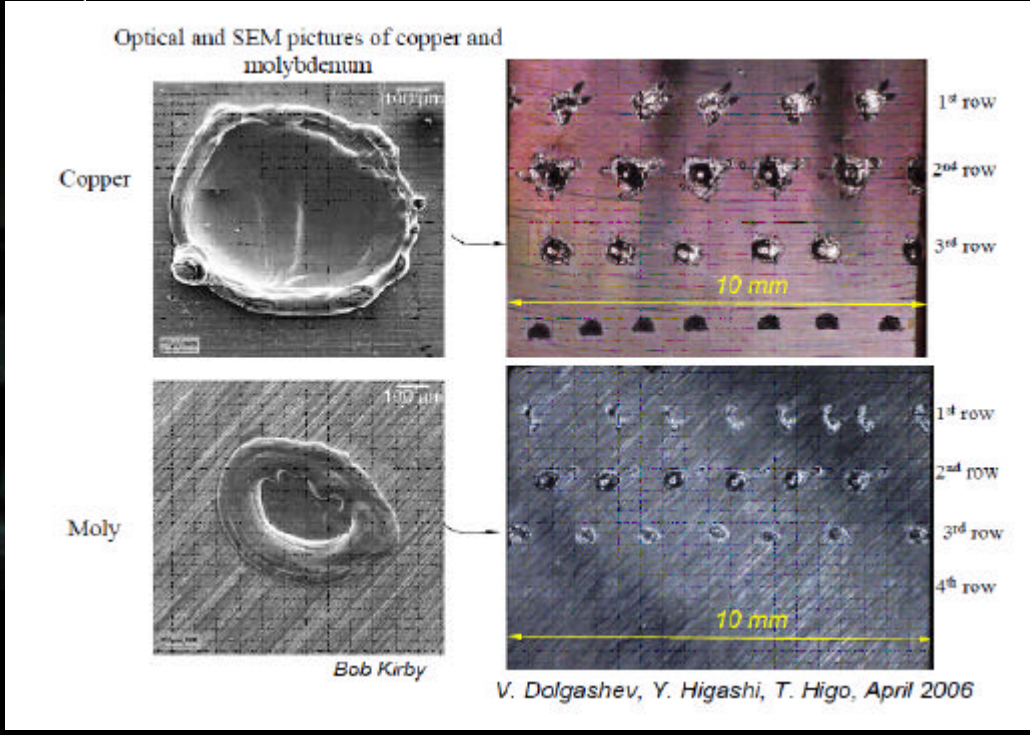
S .Tantawi, V. Dolgashev, C. Nantista (SLAC), Y.Higashi, T.Higo (KEK)

4.

Damage study on various materials done in March 2006 at KEK



Surface inspection underway at SLAC.



5.

Collaboration with CERN for CLIC

- Collaboration on
  - Precise fabrication of accelerator structure
  - Search for robust material
  - High power test of parts at X-band
  - Application of fine machining on refractory metals by Kobe Univ.
  - Trial of clean technology from superconducting cavity, such as HPR, megasonic
  - Etc.

Summary

- Various key X-band technologies are in hand.
- Application works are ongoing, mostly as collaboration programs. There are some plans to utilize an X-Band compact accelerator.
- Some of fundamental studies on high field are ongoing. Some are planned. XTF will be moved to (and reorganized at) the new place.