High Power Test Areas: Nextef

CLIC08,

Oct. 14-17, 2008

Shuji Matsumoto

Accelerator Lab., KEK

Mission of Nextef

Nextef stands for NEw X-band TEst Facility.

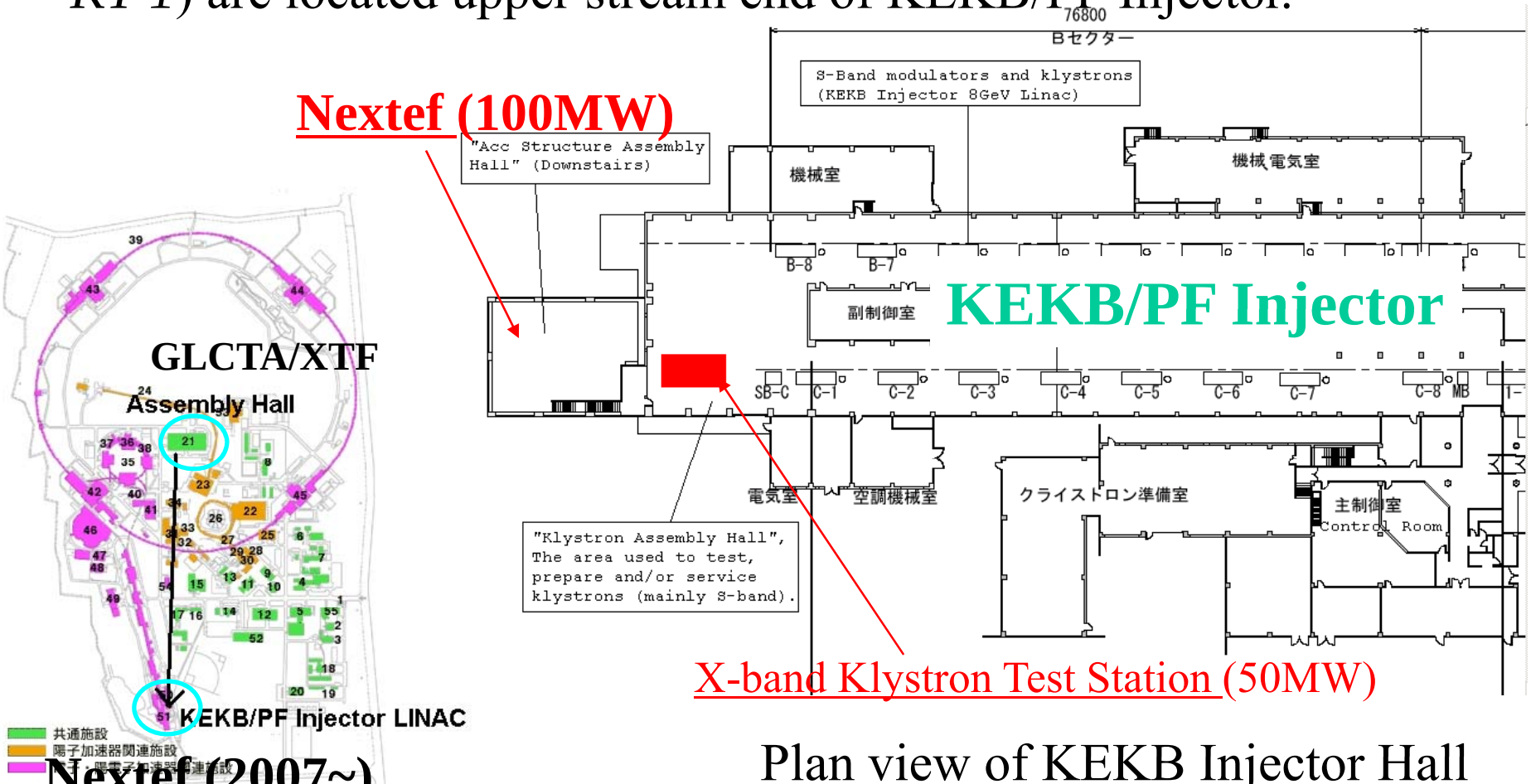
•Nextef was proposed in 2006 as a reassembled facility of old XTF. Its construction was done in 2007.
•A 100MW high power station for the X-band accelerator structure tests.

•Use of Nextef for collaboration work on developing high gradient accelerator structures (of 100MV/m or beyond) by 2011.
•T18 structure test (first test) has just started at Nextef.

•For small size fundamental studies on high gradient and RF breakdown tests such as narrow waveguides are done at KT-1 50MW station.

Location

Both *Nextef* and *X-band Klystron Test station* (We now call it *KT-1*) are located upper stream end of KEKB/PF Injector.



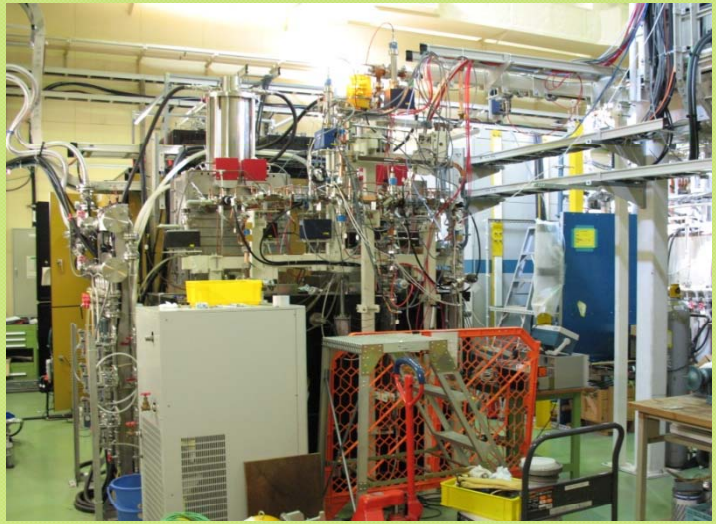
Plan view of KEKB Injector Hall

Nextef (2007~),
KLY Test Station(2006~)

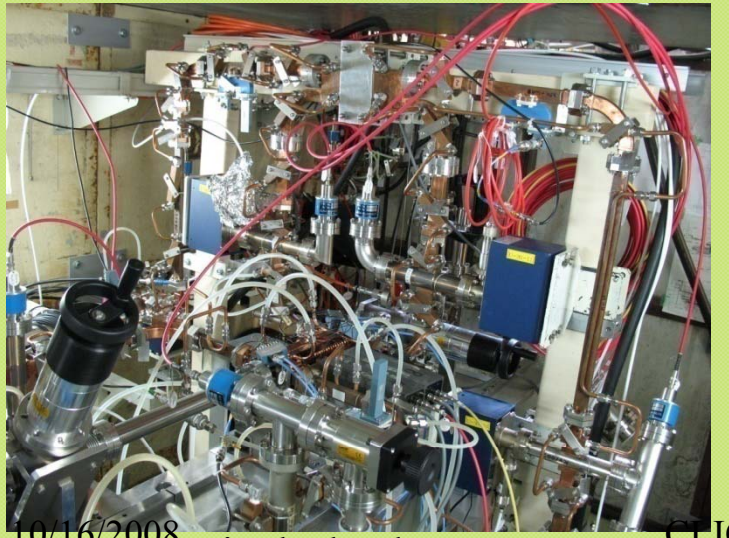
Introduction

X-band high power stations we are operating..

Nextef (100MW)

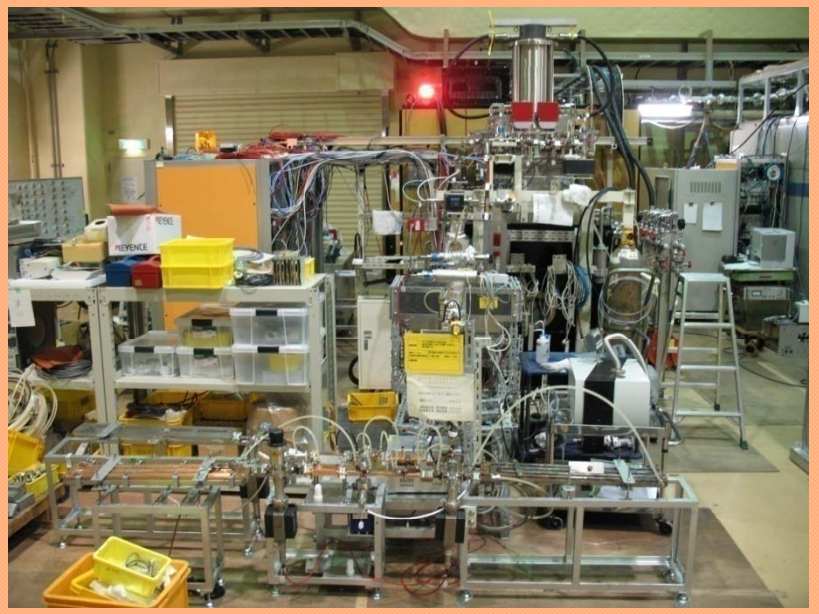


Modulator and twin klystrons



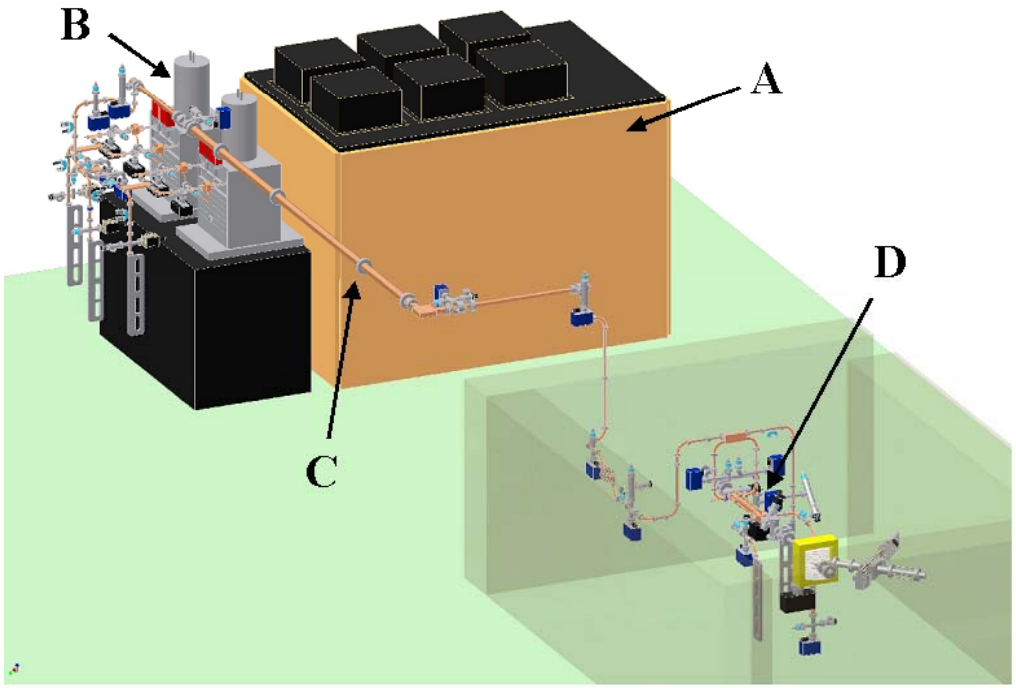
Test area in the bunker

KT-1 (50MW)



Klystron Test,
Small experiments (in Lead shield box)

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.

Features

· 11.424GHz, 100MW(50MW x2), 400ns, 50pps.

· Linked with KEKB Injector operation. 24Hr operation is possible when the injector is in operation.

· 50cm-thick concrete wall bunker.

· Local control PC linked with KEKB Injector control system. Remote access is possible.

· Acquisition and store the (log) data by LINUX and EPICS.

· DPO Oscilloscopes are prepared to record pulse-to-pulse (typically last ten pulses) waveforms when a BD event happens.

· Monitor and analyze dark current by Faraday cups, CT and analyzer magnet.

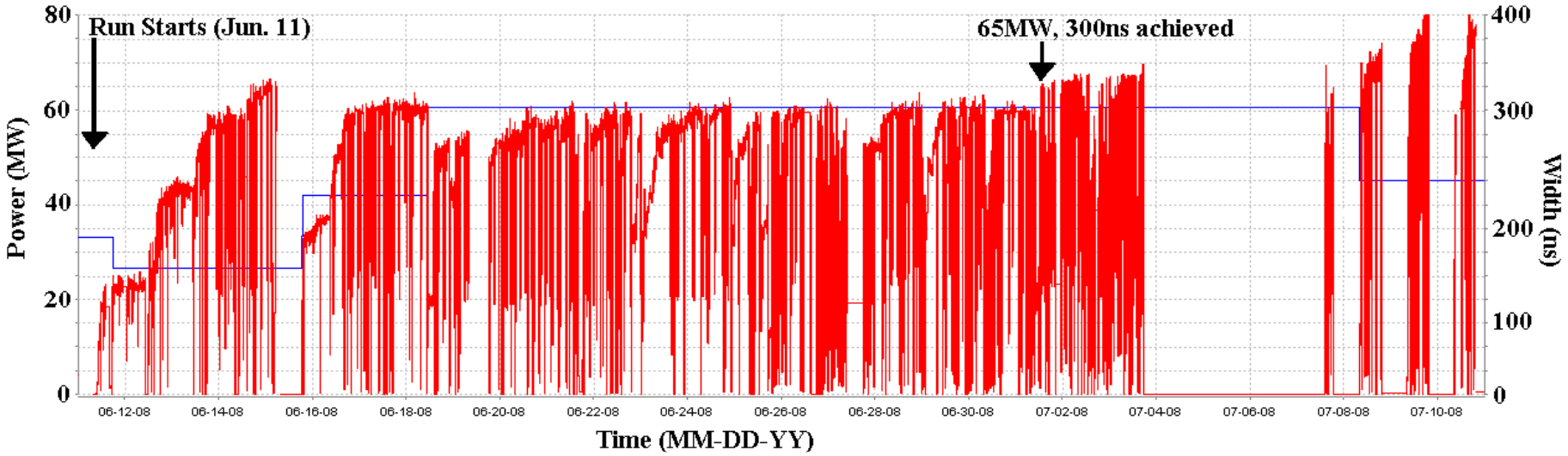
· Acoustic sensors and X-ray detectors and Q-mass monitor are prepared.

Commissioning of Nextef

year	Month	Nextef	Comment
2007	5	Nextef construction starts.	
	6		
	7		1st HG Structure Collaboratrion Meeting at CERN
	8	Major construction work done	
	9		
	10		
	11	Starts RF operation.	
	12		Injector Shutdown
2008	1		
	2		
	3		
	4		
	5		2nd HG Structure Collaboration Meeting at KEK
	6	90MW RF Prodution / w 210ns, 25pps. (65MW power feed to the structure. It suffices for T18 series structure tests.). Install KX03.	
	7	Established 60MW feed, 300ns / w KX03.	Injector shutdown Jul 4- Sep 11.
	8		
	9	T18 vg2.4 Disk #2 installed. Test started.	
	10		CLIC WS

We have no serious failure during the commissioning.

Nextef Commissioning Run with KX03 Structure: One-month history plots of the power to the structure and pulse width



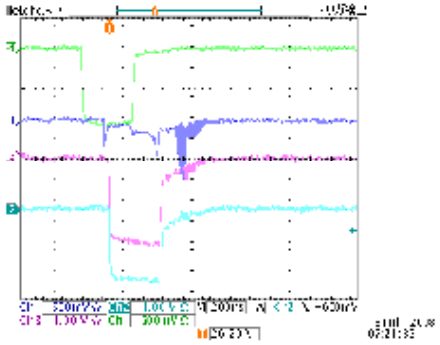
Jul. 4 →

Injector scheduled shutdown

Example of observed waveform with KX03

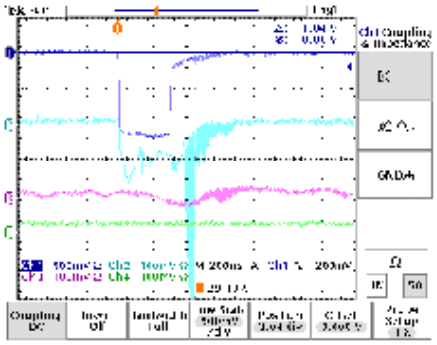
BD at KX03

Event 07:21:25 July 3, 2008



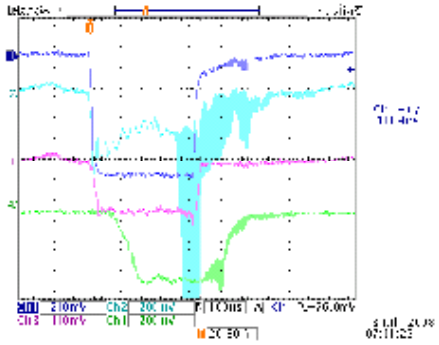
Klystron Output

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



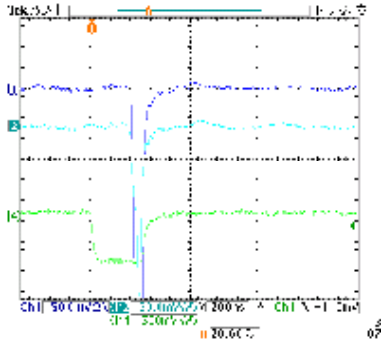
Power combination

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



Accelerator Structure

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



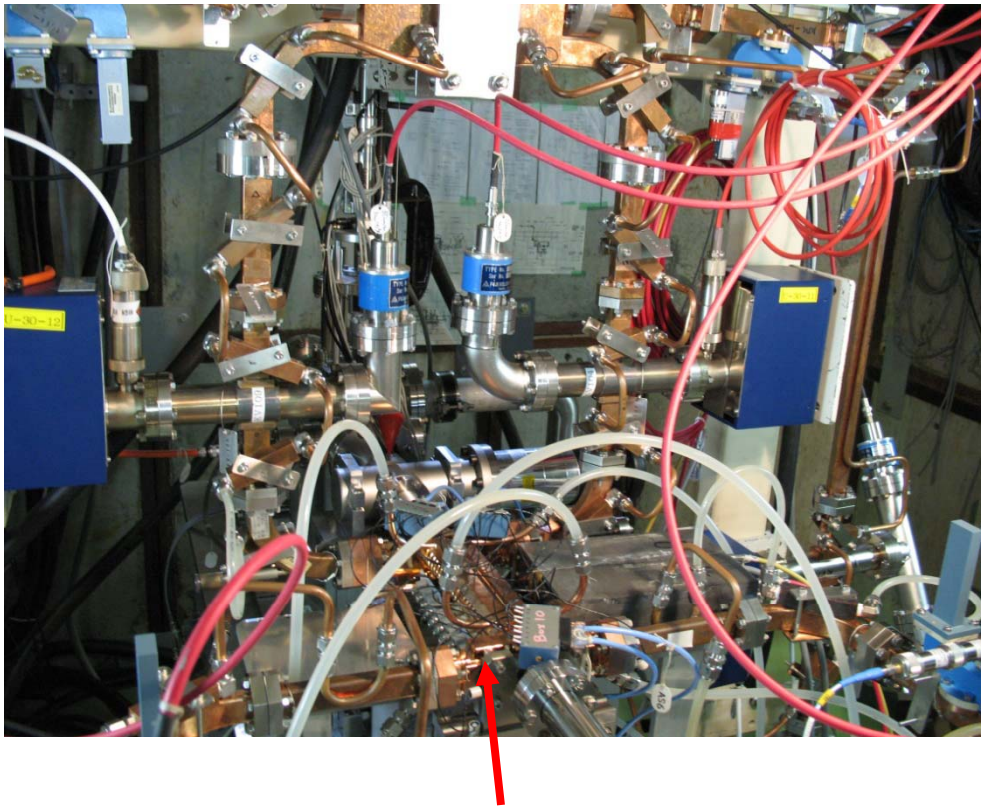
Faraday cups

Ch1: FC_UP
Ch2: FC_DN
Ch3:
Ch4: ACC_IN

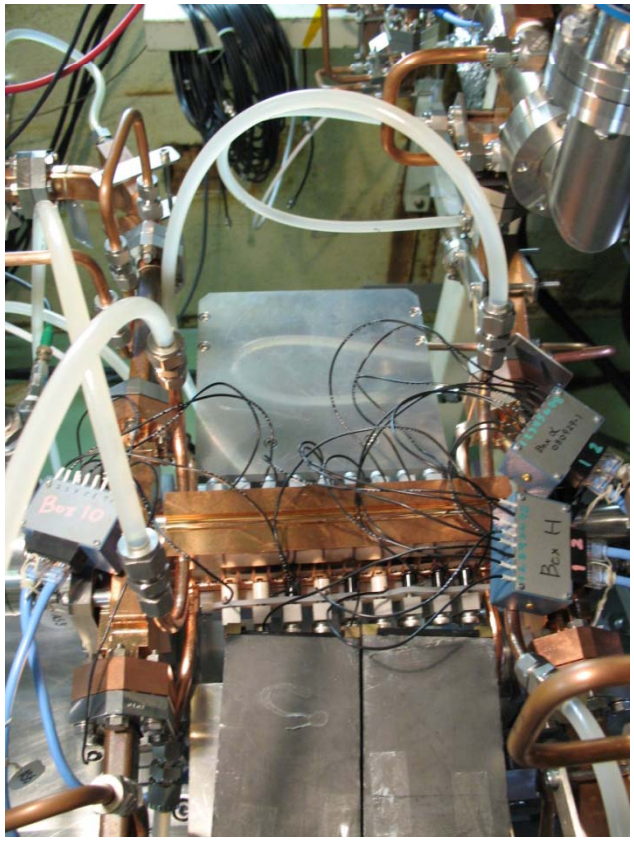
Commission detectors with these BD events.

Current Status of Nextef

The test of T18_vg2.4_Disk#2 started on Sep 29.



T18_vg2.4_Disk#2

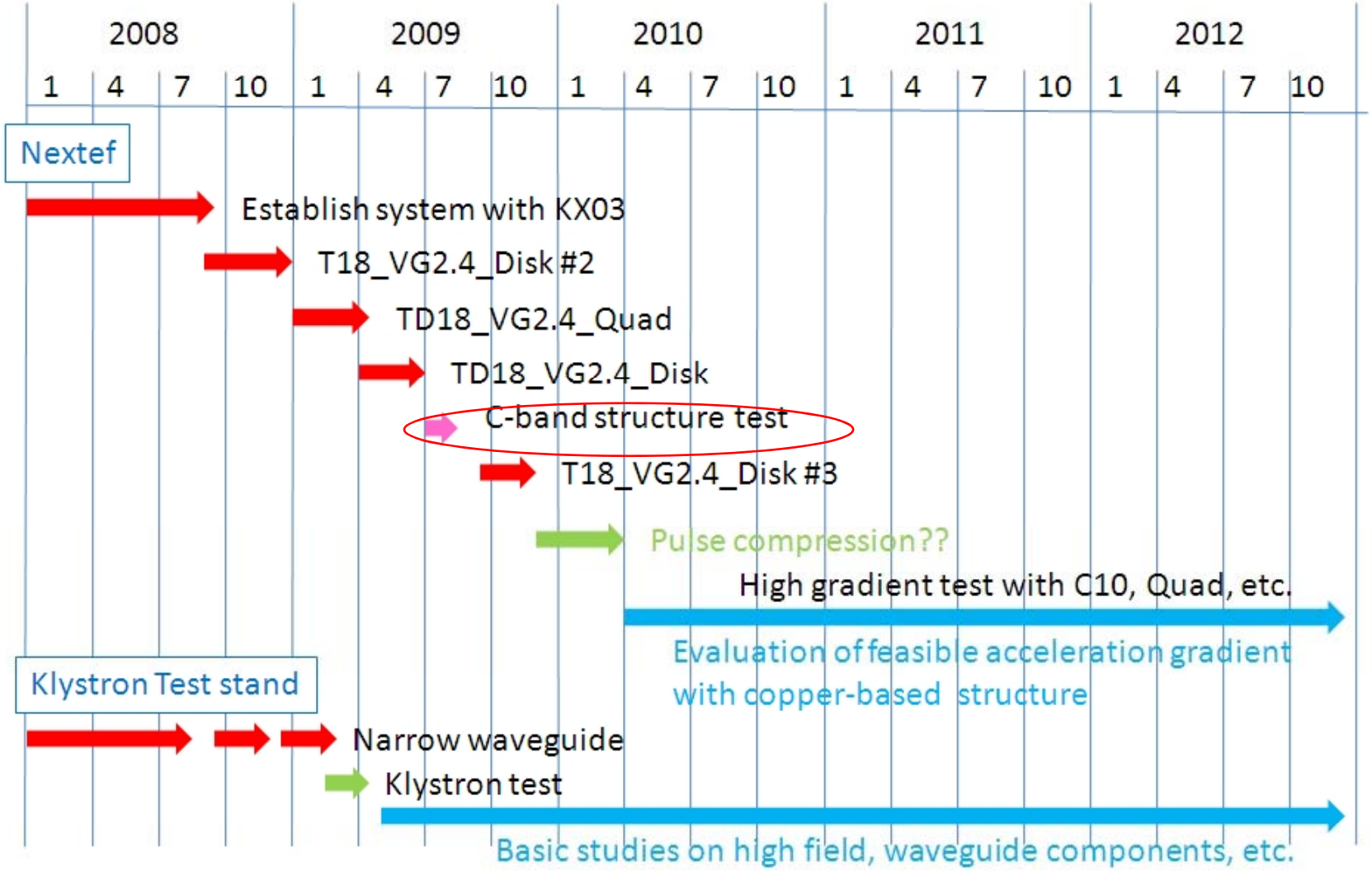


Acoustic sensors

Future Plans for Facility Improvement and Other Related Activity

- C-band test
- X-band Pulse compression
- X-band klystron

Test Schedule: Nextef and KT-1



C-band test

•C-band R&D project is for upgrading the positron injection energy in Super KEKB project.

•Four 1m long Acc structures work in Injector. Additional two are to be installed in 2009 and 2010 (one per each year).

•It is necessary to test them in late spring 2009. The duration of the test will be 2 months.

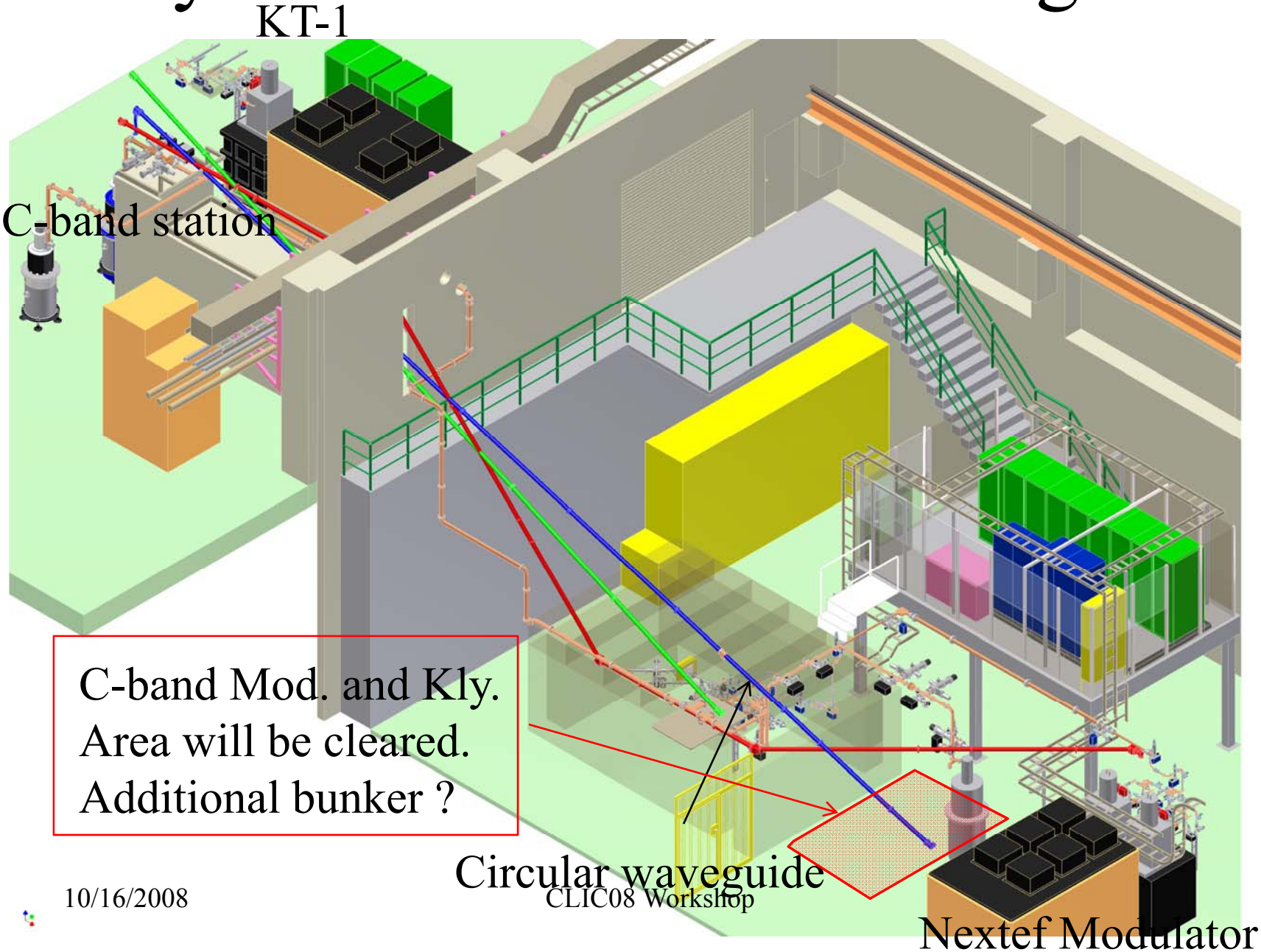
The bunker of Nextef will be occupied by the processing of these structures.

C-band test plan

C-band power is provided from the power stand located in next door through circular waveguide.
Installation of the waveguide will be done around Dec. or Jan. 2009.

The bunker can be expanded (additional 2m x 4m area) after C-band modulator and C-band klystron in Nextef hall being removed. It may be done in 2009.
The expansion is preferable (or necessary) to do both X-band and C-band tests in an efficient way.
The plan is now under examination.

Layout of the circular waveguide



X-band Pulse Compression plan

•Each of C-band structure test is to be completed in 2months.

•If Φ80 circular waveguide for the C-band test can be used for the pulse compression system in our X-band system, it sounds pretty nice.

•Realize peak power of 150MW with 150ns pulse width.
Each klystron produces 30 MW output,

→ 60MW (combined) ×gain 3 = 180MW

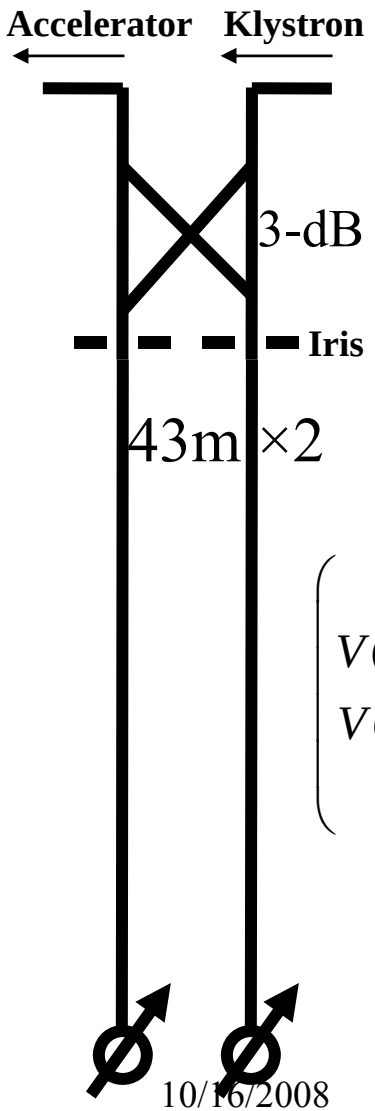
→ looks like 150MW available.

•There are some possible options…
(A single High-Q cavity option was proposed for us).
It looks feasible to employ the single circular waveguide scheme.

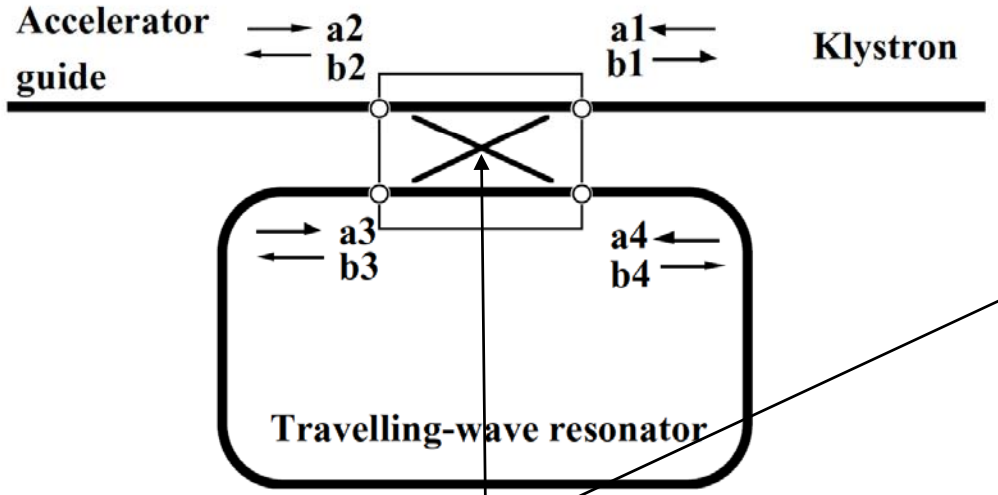
Consideration about Delay Line Type

M.Yoshida

SLED-II

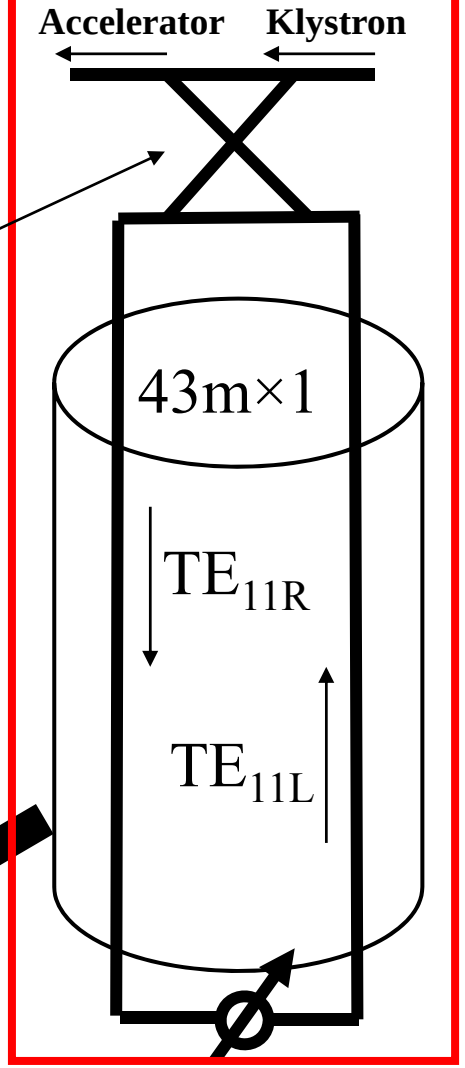


Traveling Wave
Pulse Compressor



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

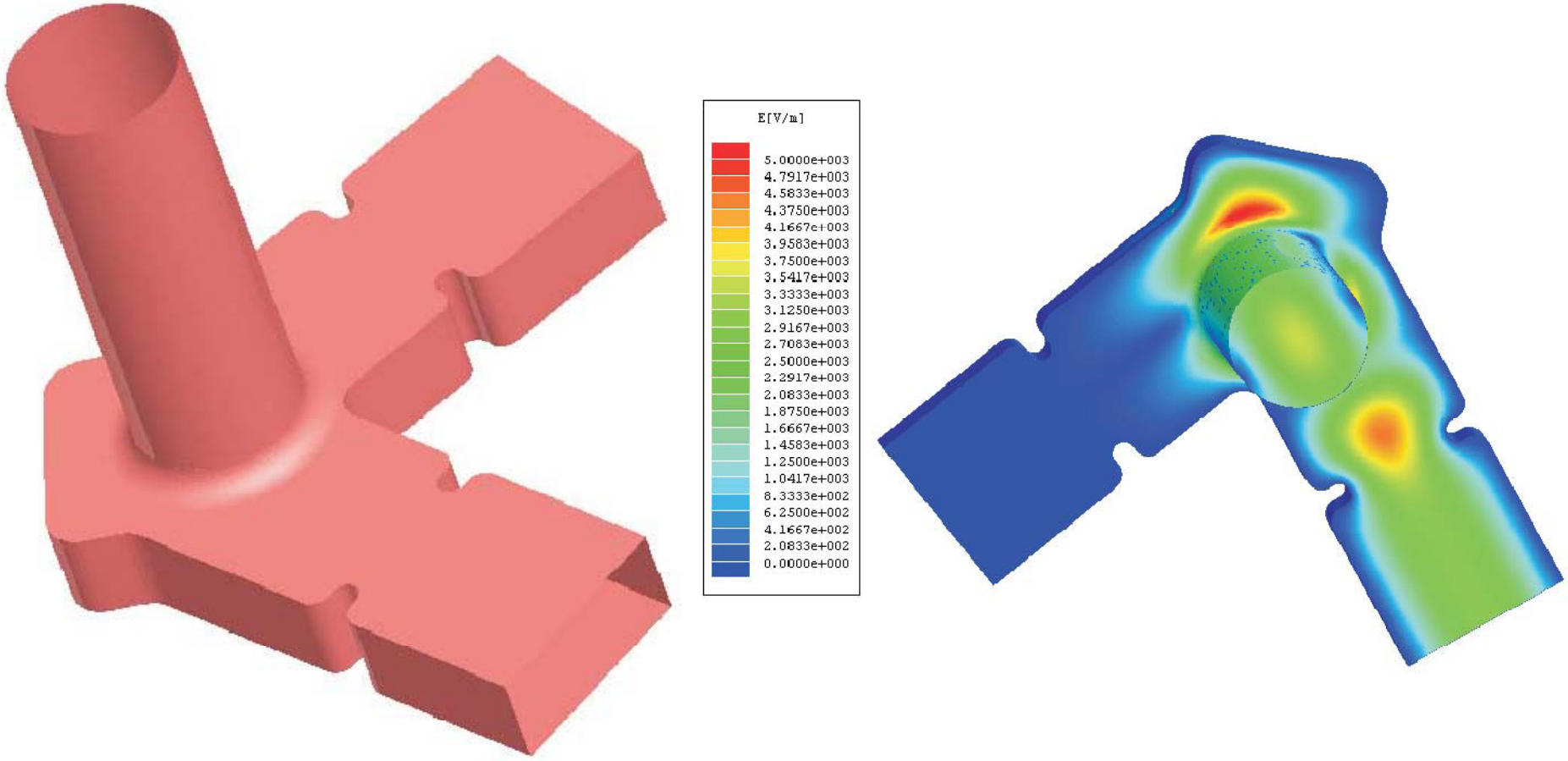
Traveling Wave
Single Delay Line
Pulse Compressor



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

Mode Converter

WR90 Rectangular TE10 → Circular TE11(R)

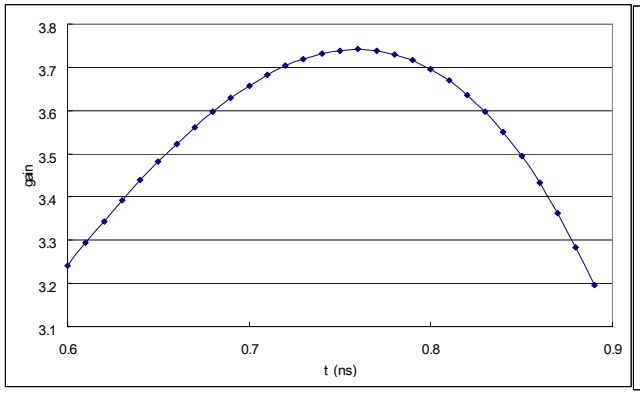


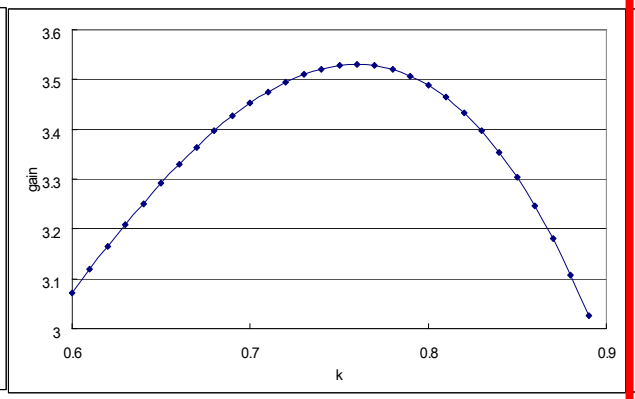
Ideal Gain of Traveling Wave Delay Line Pulse Compressor

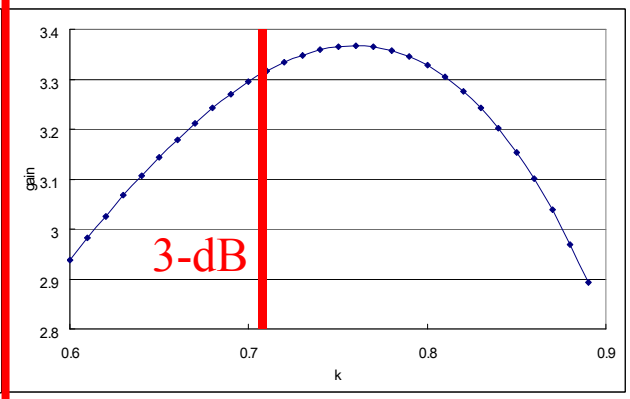
$86m\times(TE_{01})$= -0.24dB/turn

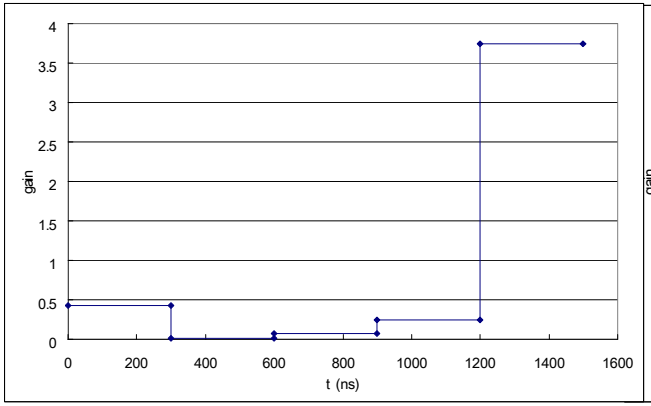
$43m\times(TE_{01}+TE_{11})$= -0.44dB/turn

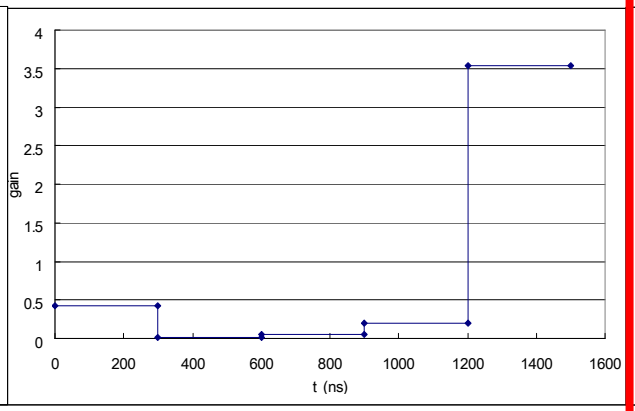
$22m\times(TE_{11R}+TE_{11L}+TE_{12R}+TE_{12L})$
$= 43m\times(TE_{11R}+TE_{11L})$ = -0.6dB/turn

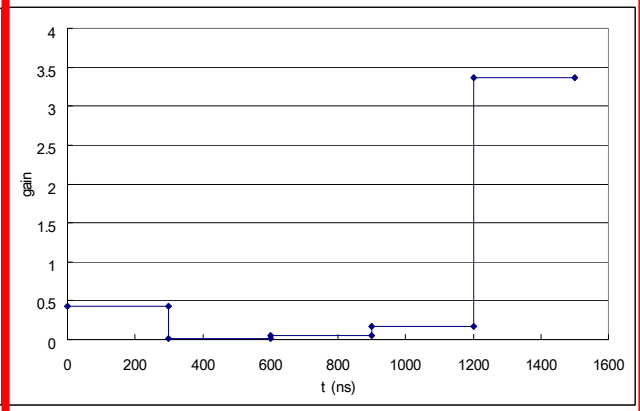












Gain=3.74

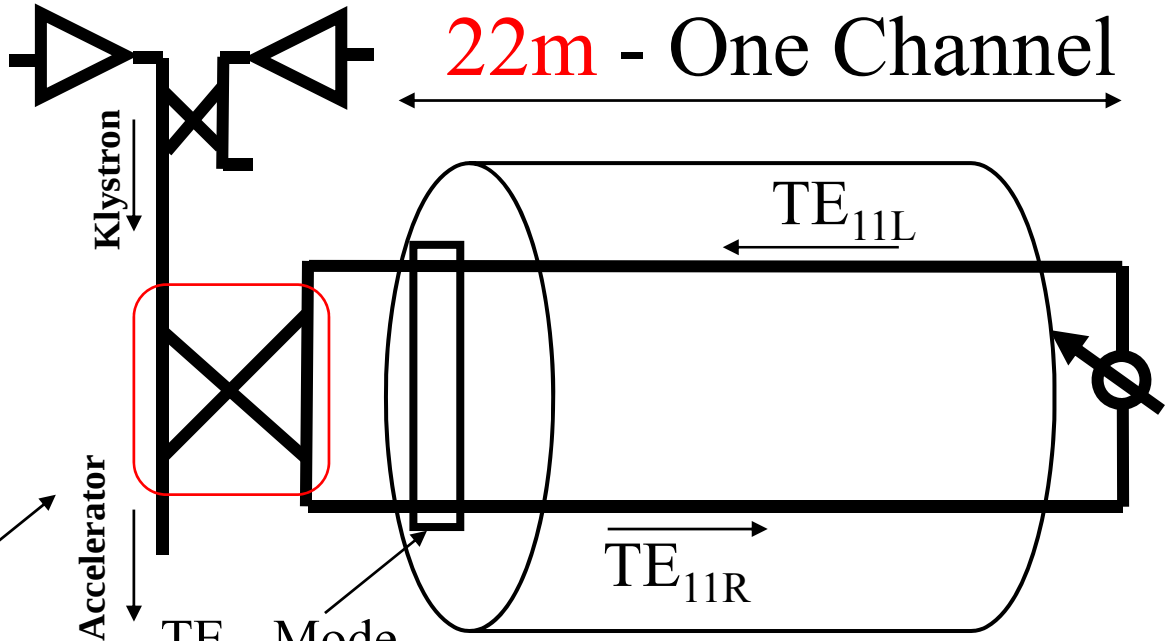
Gain=3.53

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

Strategy for Nextef

M.Yoshida

22m - One Channel



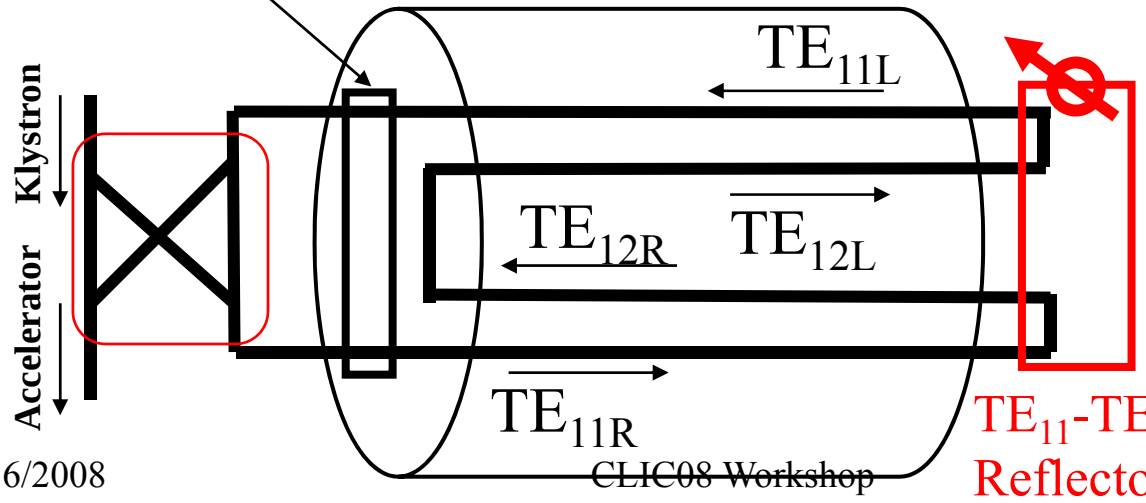
30MW×2 Klyston
×gain=3
→ 180MW

750ns → 150ns
Gain = 3.6 @ 3dB

3dB Hybrid

TE_{11} Mode Converter

Upgrade using higher mode



1500ns → 300ns
Gain = 3.3 @ 3dB

X-band klystrons

We have two(Nextef)+one(KT-1) klystrons in operation and one spare.
(The spare klystron needs to be conditioned: done in the end of this FY at KT-1.)

The performance of our X-band ppm focus klystron has a limit in available peak power and pulse width by the RF pulse tearing events.

Multi-Beam Klystron: The design study has been doing at KEK.
We have no definite plan to construct it.

An idea was proposed recently to use our solenoid klystrons with SC magnet. Our solenoid focus klystron have not shown (severe) pulse tearing events. These klystrons can be our spare. Design work has not started yet.

Additional two topics

- Solid-state Amplifier with GaN HEMT
- Waveguide valve

Possible replacement of TWT power amplifier by GaN HEMT*

GaN HEMT is a promising device for producing several 10W CW power in C, X and Ku band. It is believed as a successor of GaAs FETs.

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

***High Electron Mobility Transistor**

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

GaN HEMT

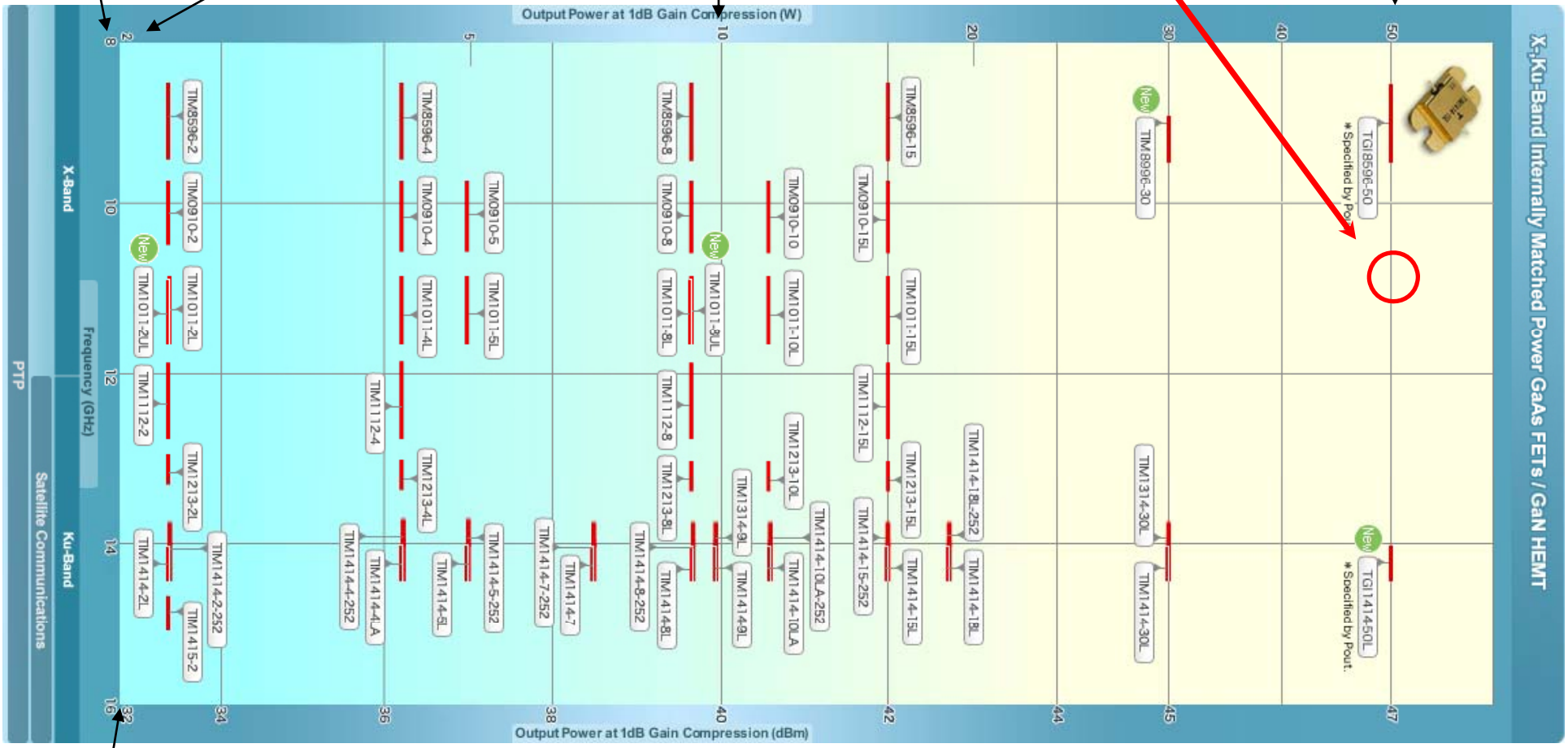
Frequency/Power

8GHz 2W

10W

Our Target is 11.4GHz 50MW

50W



16GHz

Proposed spec 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 IDSset≅1.5A f = 11.374 to 11.474GHz @Pin = 41.5dBm	dBm	46.0	47.0	—
Drain Current	IDS1		A	—	5.0	6.0
Power Added Efficiency	ηadd		%	—	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)

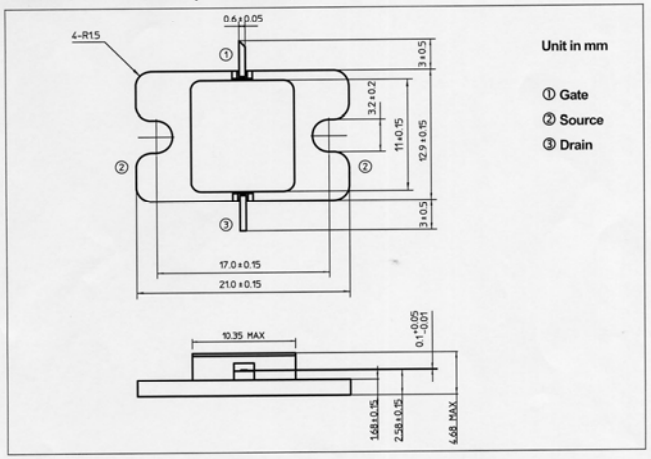
CHARACTERISTICS	SYMBOL	CONDITIONS	UNIT	MIN.	TYP.	MAX.
Transconductance	gm	VDS= 5V IDS= 5.0A	S	—	4.5	—
Pinch-off Voltage	VGSoff	VDS= 5V IDS= 23mA	V	-1	-4	-6
Saturated Drain Current	IDSS	VDS= 5V VGS= 0V	A	—	15	—
Gate-Source Breakdown Voltage	VGSO	IGS= -10mA	V	-10	—	—
Thermal Resistance	Rth(c-c)	Channel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

TGI1011-50-771

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.

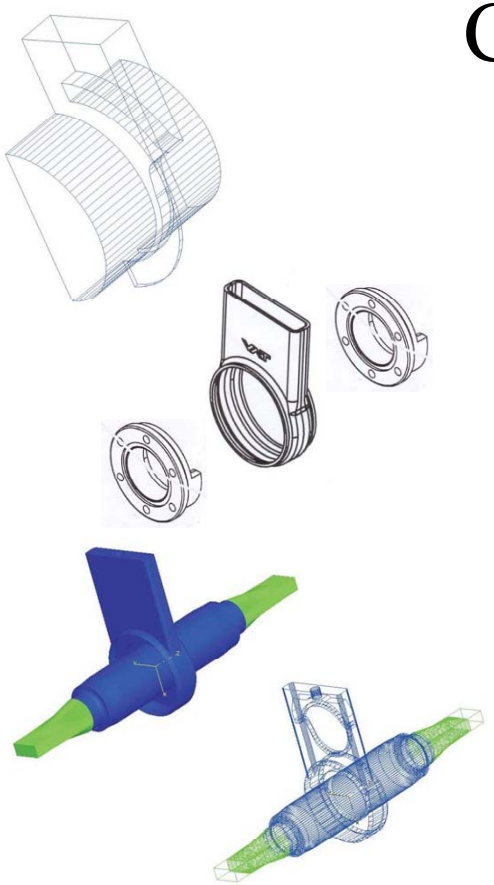
The information contained herein is presented only as a guide for the application of our products. No responsibility is assumed by TOSHIBA for any infringements of patents or other rights of third parties which may result from its use. No license is granted by implication or otherwise under any patent or patent rights of TOSHIBA or others. The information contained herein is subject to change without prior notice. It is therefor advisable to contact TOSHIBA before proceeding with design of equipment incorporating this product.

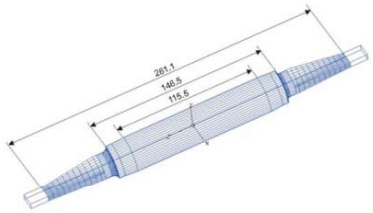
TOSHIBA CORPORATION August, 2008

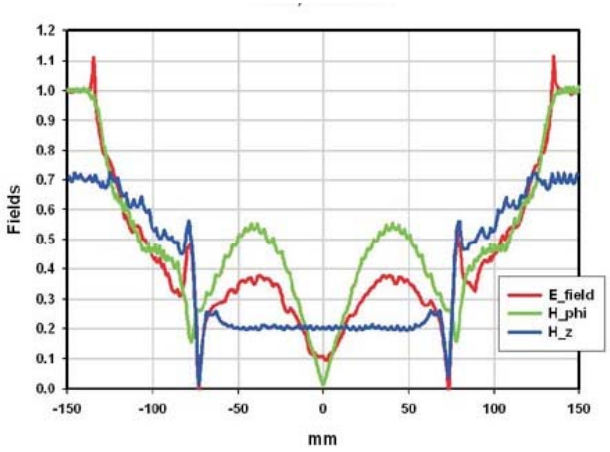
We have asked the manufacturer to make the devices for us.
We are going to check the performance of the device and
if it is OK, we are going to make an amplifier with them.

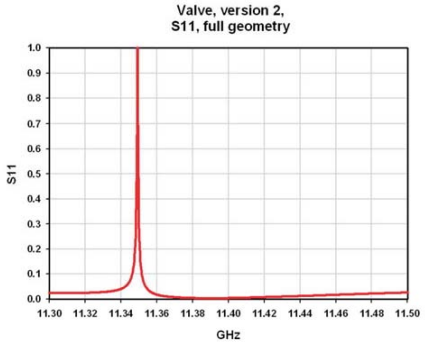
Compact waveguide valve designed

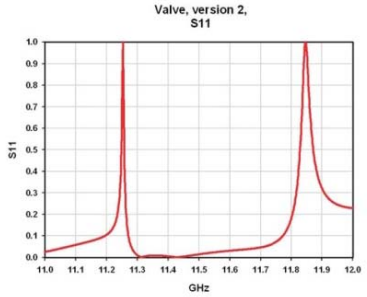
TE11 mode to make the device compact
Using VAT existing GV with some modification such as
Edge rounding, vacuum seal device far from pipe, etc.











Now under mechanical design
To be made in this fiscal year
To be tested somewhere soon

Sergey Kazakov

Summary

1. Nextef produced combined power of 100MW. 75MWpower available for tests.
2. Test of T18_vg2.4_Disk #2 has been started (Toshi Higo's talk).
3. Nextef will run for few years for the tests of the structures of collaboration among KEK, CERN and SLAC.
4. KT-1 50MW X-Band Klystron Station is running. Tests of Narrow Waveguides continues. Conditioning of a spare klystron is done in this FY.
5. Future plans such as Pulse Compression has been started.
6. Collaboration in the structure tests as well as the future projects are welcome.