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DRFS Test Preparation at S1-G

S. Fukuda/KEK

Current program

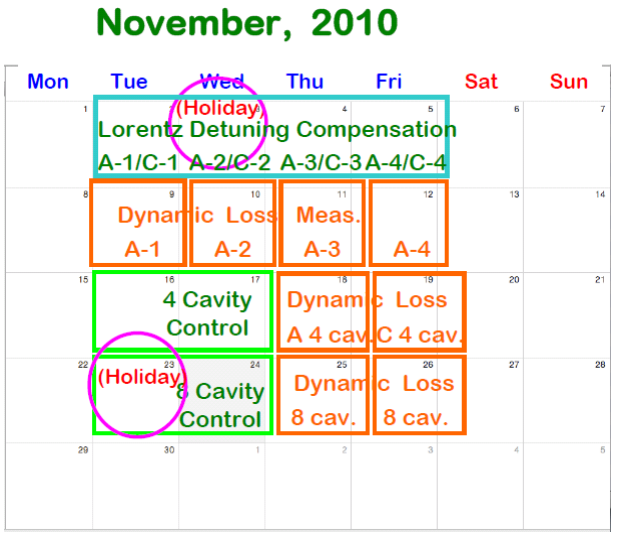
- 2 units DRFS for S1 global project(2010)
  - RF source of DRFS comprises of a prototype DC power supply, a modulating-anode (MA) modulator and 2 proto-type MA klystrons.
  - Power distribution system (PDS) employs the circulator-less system to show the feasibility of proposed DRFS PDS.
  - Power supply system has a simple crowbar circuit using a gap switch, available HV relays, but does not include the bouncer circuit.
  - LLRF feedback is also introduced to test the DRFS LLRF system.

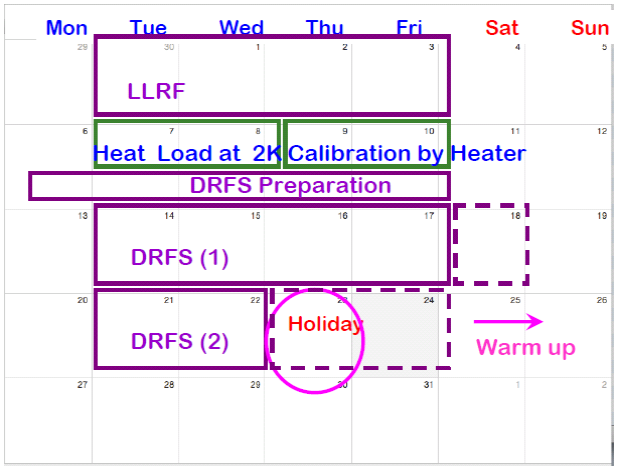
- Prototype DRFS klystron outputting medium power of 750kW was designed and manufactured in 2009 and completed in 2010.
  Second tube is manufactured in 2010.
  Various evaluations will be performed after the S1-Global HLRF test.

- PDS performance using high isolation magic-tee without a circulator is investigated for 2-cavity system under the LLRF feedback.
  Crosstalk and diagnoses of cavity parameters at the pulsed tail are studied in S1-Global test.

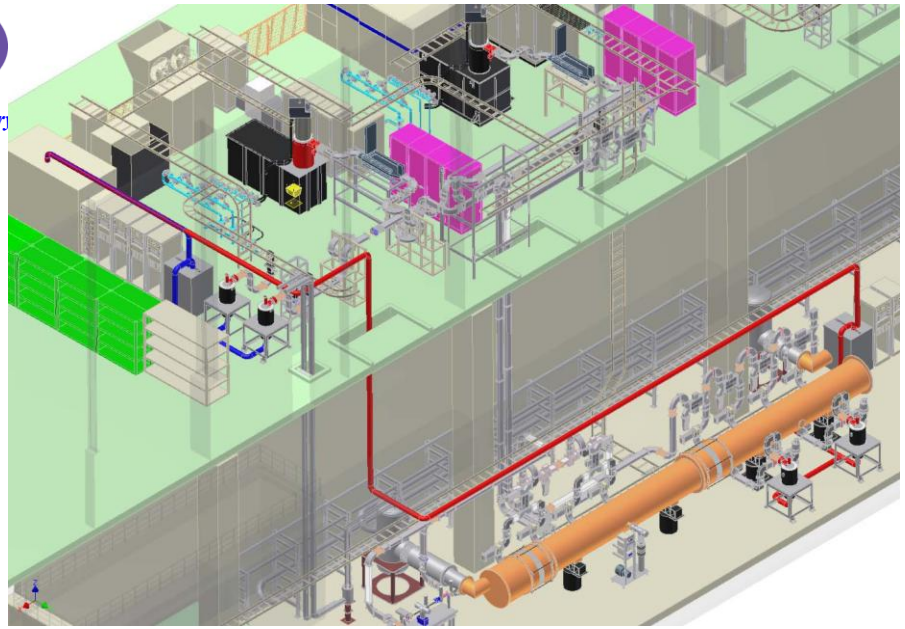
Schedule for DRFS S1 global (Next 2-months)

- Due to the trouble of RF source #1, S1 schedule delayed for 2-3 weeks.
- DRFS test is allocated to the last of S1-global and will be conducted in last 1 and half weeks of last stage if we don't extend the schedule.
- Klystrons are delivered.
- Delivery of a DC p/s and a modulator is delayed.
- HLRF test be completed in middle of November and moved to tunnel.





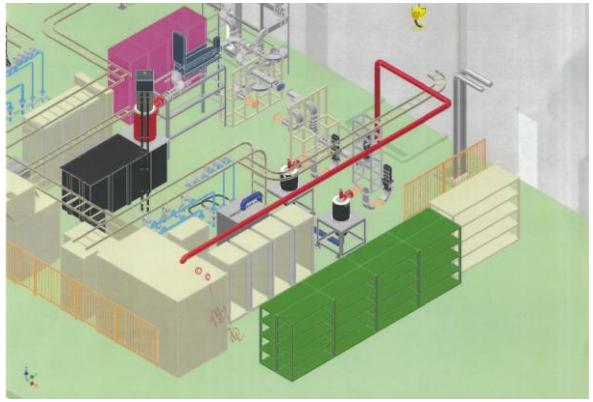
DRFS Demo in S1-Global



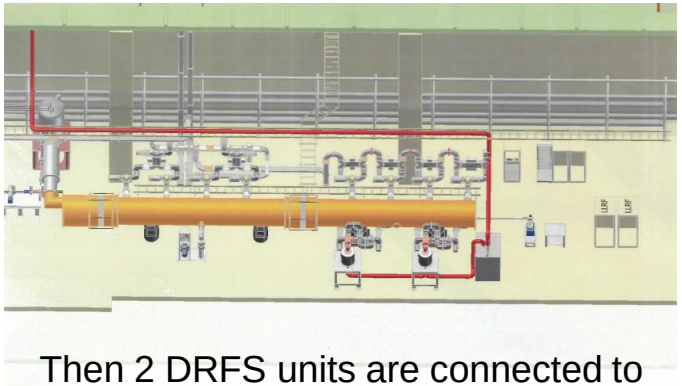
DRFS demonstration will be Prepared in the end of S1-global: December of 2010.

2 units DRFS

Birds eye view of STF site



First evaluation test is done in klystron gallery



Then 2 DRFS units are connected to the four cavities in the cryomodule.

System description and progressing R&D (1)

- MA Modulator : based on the J-Parc MA modulator (120kV) and simplified.

- Proto-type switching regulators are ordered.

- DC Power supply without Bouncer circuit are being manufactured.
- HV relay R&D
- Reliable Gap Switch as a Crowbar circuits are planned.

- Klystron and klystron socket are manufactured. One is soon arriving and No. 2 will be delivered in October.

System description and progressing R&D (2)

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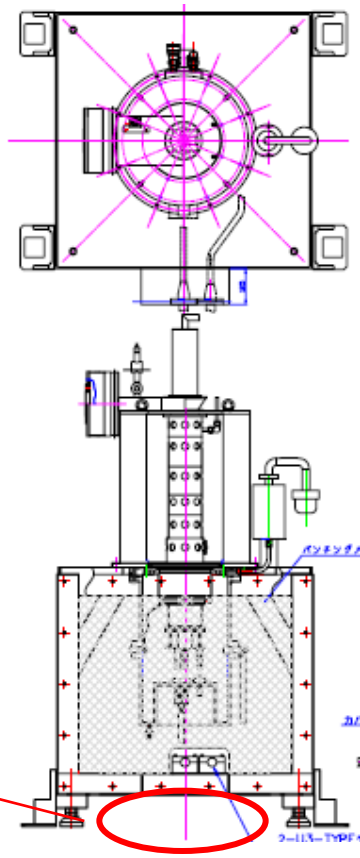
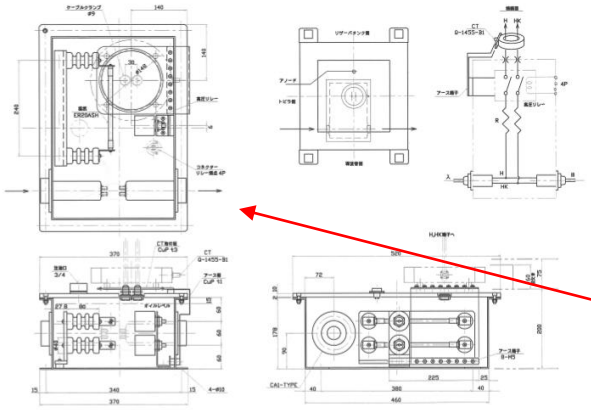
- Klystron and klystron socket are manufactured.

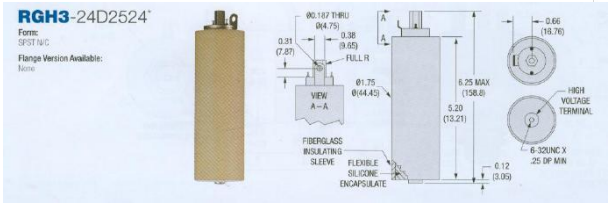
• Prototype DC Power supply and MA modulator are under manufacturing.
• No Bouncer
• Spark-gap as the Crowbar



High Voltage Connection Box
At the tentative demonstration



HV relay R&D
With Jennings Corp.



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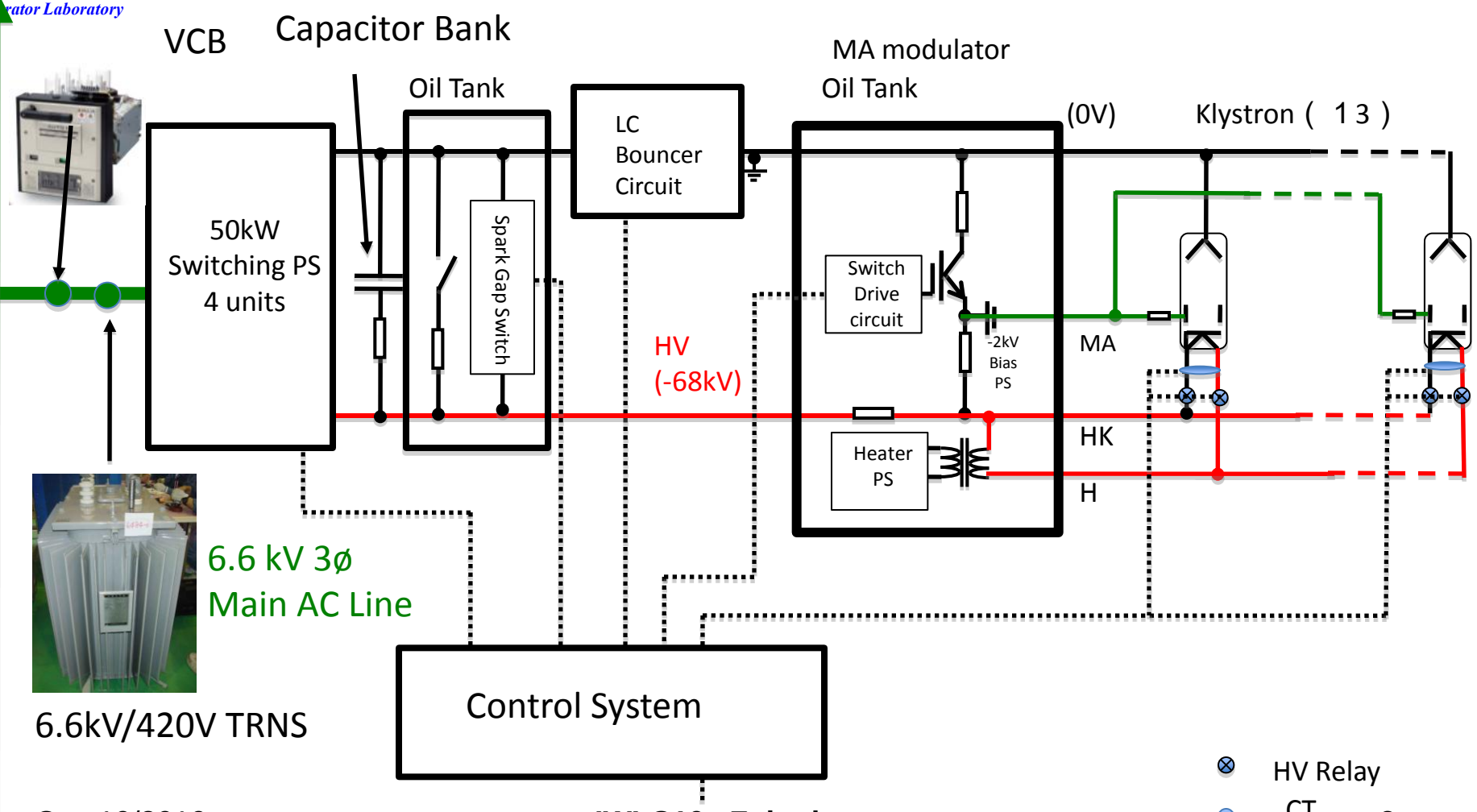
Prototype DRFS Klystrons

PS system for DRFS (one unit)



DRFS Klystron Specification

800 kW Option Specification			
Klystron	Frequency	1.3	GHz
	Peak Power	800	kW
	Average Power Output	6.00	kW
	RF pulse width	1.5	ms
	Repitition Rate	5	Hz
	Efficiency	60	%
	Saturated Gain		
	Cathode voltage	65.8	kV
	Cathode current	20.3	A
	Perveance(Beam@65.8k	1.2	micro Perv
	(Gun@54.4 kV)	1.56	micro Perv
	Life Time	120,000	hours
	# in 3 cryomodule	13	
	Focusing	Permanent magnet	
	Type of Klystron	Modulated Anode Type	
DC Power supply per 3 cryomodules			
	# of klystron (3 cryomod	13	
	Max Voltage	71.5	kV
	Peak Pulse Current	263.4	A
	Average Current	2.9	A
	Output Power	190.7	kW
	Pulse width	2.2	ms
	Repitition Rate	5	Hz
	Voltage Sag	<1	%
	Capacitor	26	mF
Bouncer Circuit			
	Capacitance	260	mF
	Inductance	4.9	mH
M. Anode Modulator			
	Anode Voltage	54.4	kV
	Anode Bias Voltage	-2	kV

Proto Type DRFS Klystron for S1 Global

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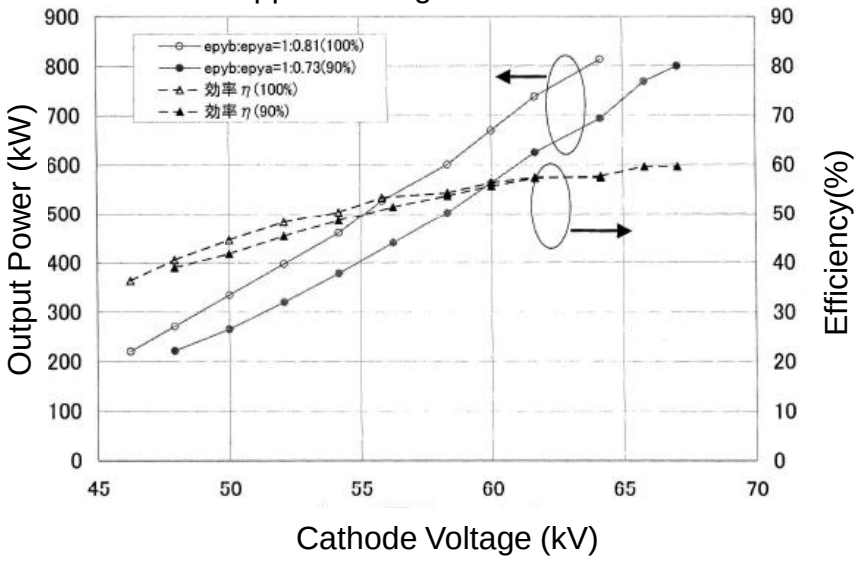
In FY2010, two proto-type DRFS klystrons are manufactured in order to demonstrate DRFS in S1 global in KEK.

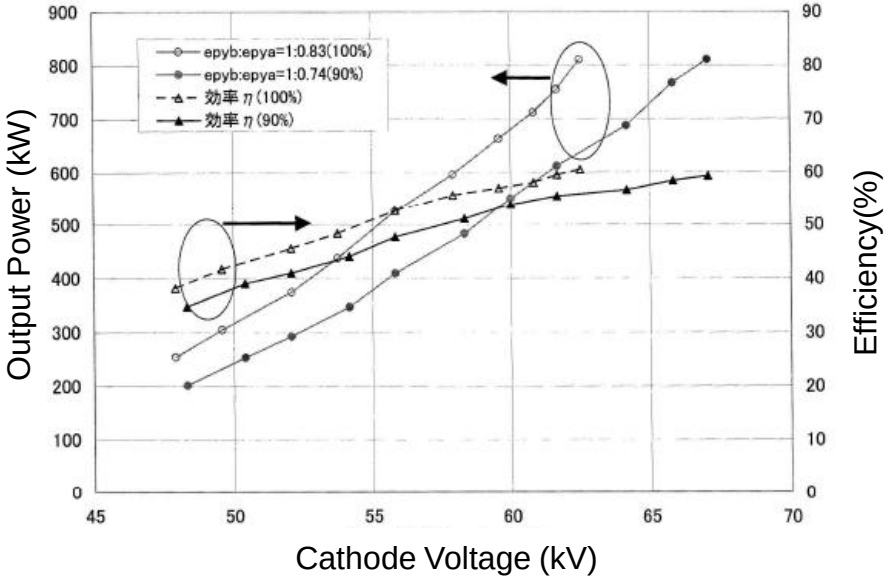
- In original specification of DRFS klystrons, output power was 750kW, but after the discussion about the usage of 31.5MV/m+20% sc cavity, output power is increased to 800kW. In Toshiba test before delivery, 2 klystrons successfully output more than 800kW.
- Following data were obtained in factory test.
  - No. 1 DRFS klystron: 806.7kW at 67.1kV (Micro-perveance=1.15), Eff.=**60.1**%
    - » 813.0kW at 64.2kV (Micro-perveance=1.36), Eff.=57.4%
  - No. 2 DRFS klystron: 811.6kW at 67.1kV (Micro-perveance=1.17), Eff.=59.4%
    - » 810.5kW at 62.5kV (Micro-perveance=1.37), Eff.=**60.5**%
- In the end of October to November, KEK starts the acceptance test with MA modulator and DC power supply which has manufactured in FY2010 using RF dummy load.
- In December, these klystrons are operated as DRFS demonstration connecting to super-conducting cavities.

Output Characteristics (at Saturation)

E37501 #1 Saturation power vs applied voltage



E37501 #2 Saturation power vs applied voltage



No. 1 DRFS klystron:
806.7kW at 67.1kV (Micro-perv.=1.15),
Eff.=**60.1**%

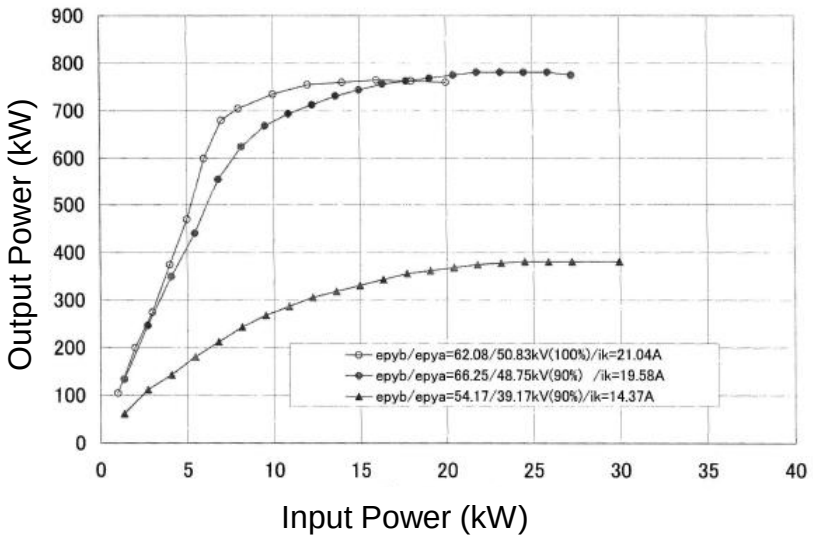
813.0kW at 64.2kV (Micro-perv.=1.36),
Eff.=57.4%

No. 2 DRFS klystron:
811.6kW at 67.1kV (Micro-perv.=1.17),
Eff.=59.4%

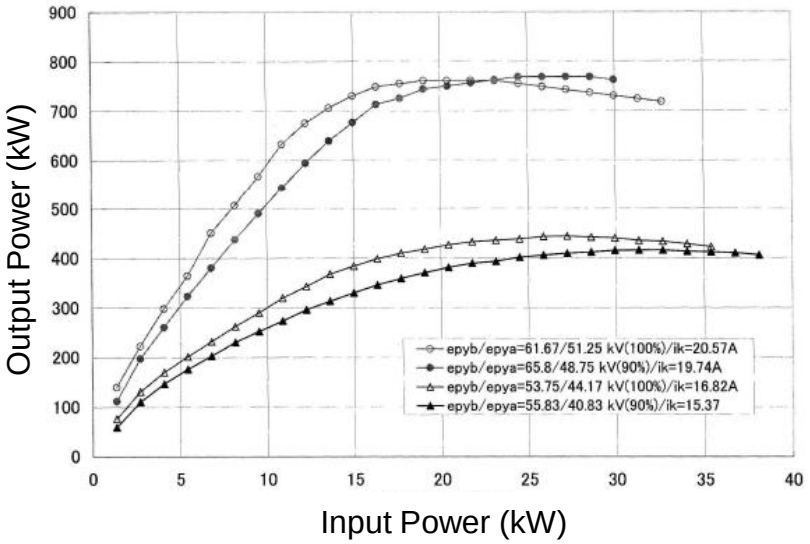
810.5kW at 62.5kV (Micro-perv.=1
Eff.=60.5%

Input-output Characteristics

E37501 #1 Input-output characteristics



E37501 #2 Input-output characteristics



Both tubes have good input-output characteristics without any Unstable operating point. Saturation power of more than 800kW is Obtained in both tubes.

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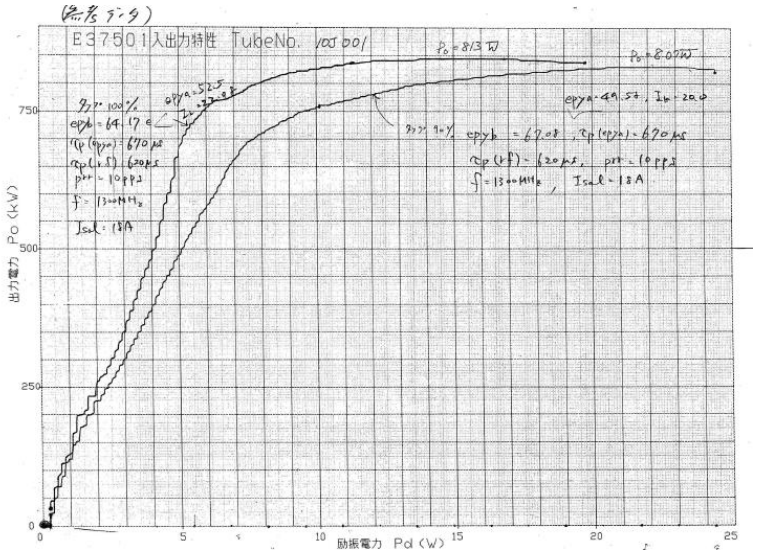
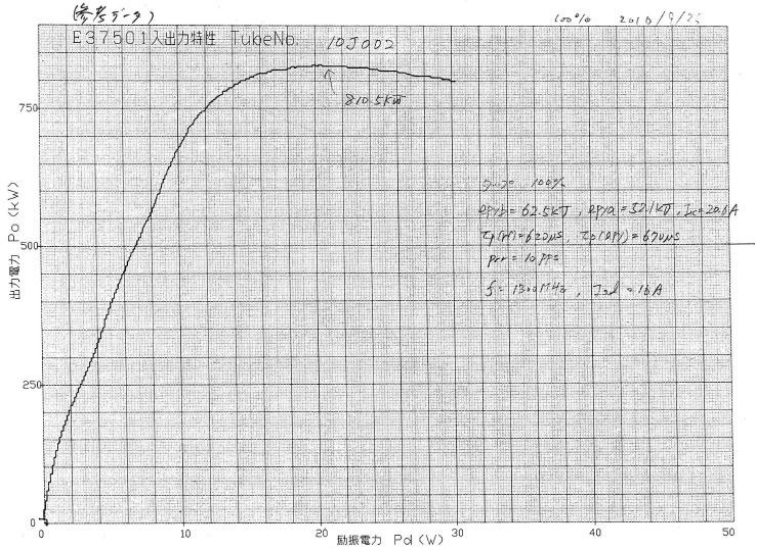
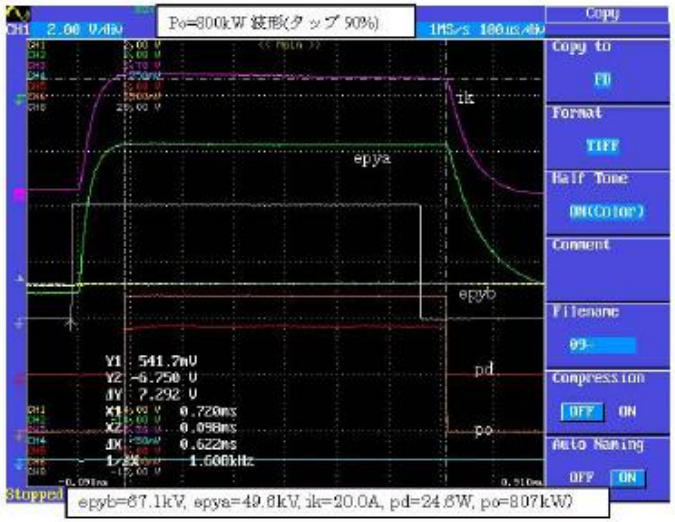
800kW Output

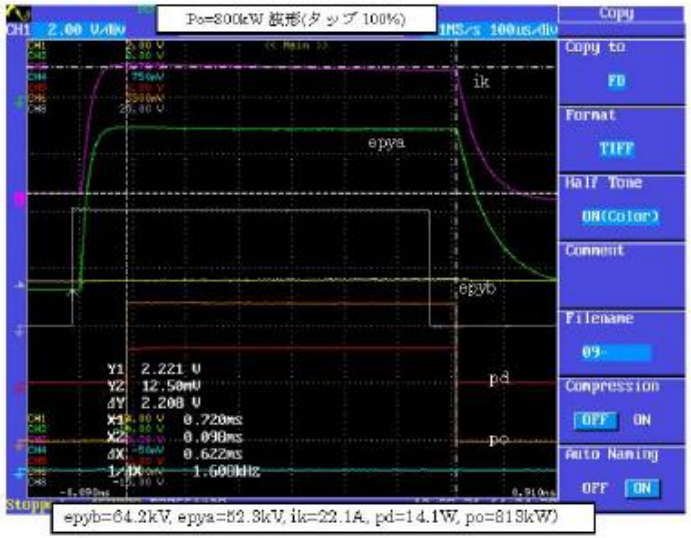




Waveform



RF waveform of P0=807kW
Resistive divide ratio of 90%
=Microperveance of 1.15



RF waveform of P0=819kW
Resistive divide ratio of 100%
=Microperveance of 1.36

DRFS Klystron in STF

2 DRFS Klystrons were delivered.

DRFS klystron is connected to water load to check the performance.

Tank assemblies for the testing. Relay and CT to detect over-current are set outside in this case.

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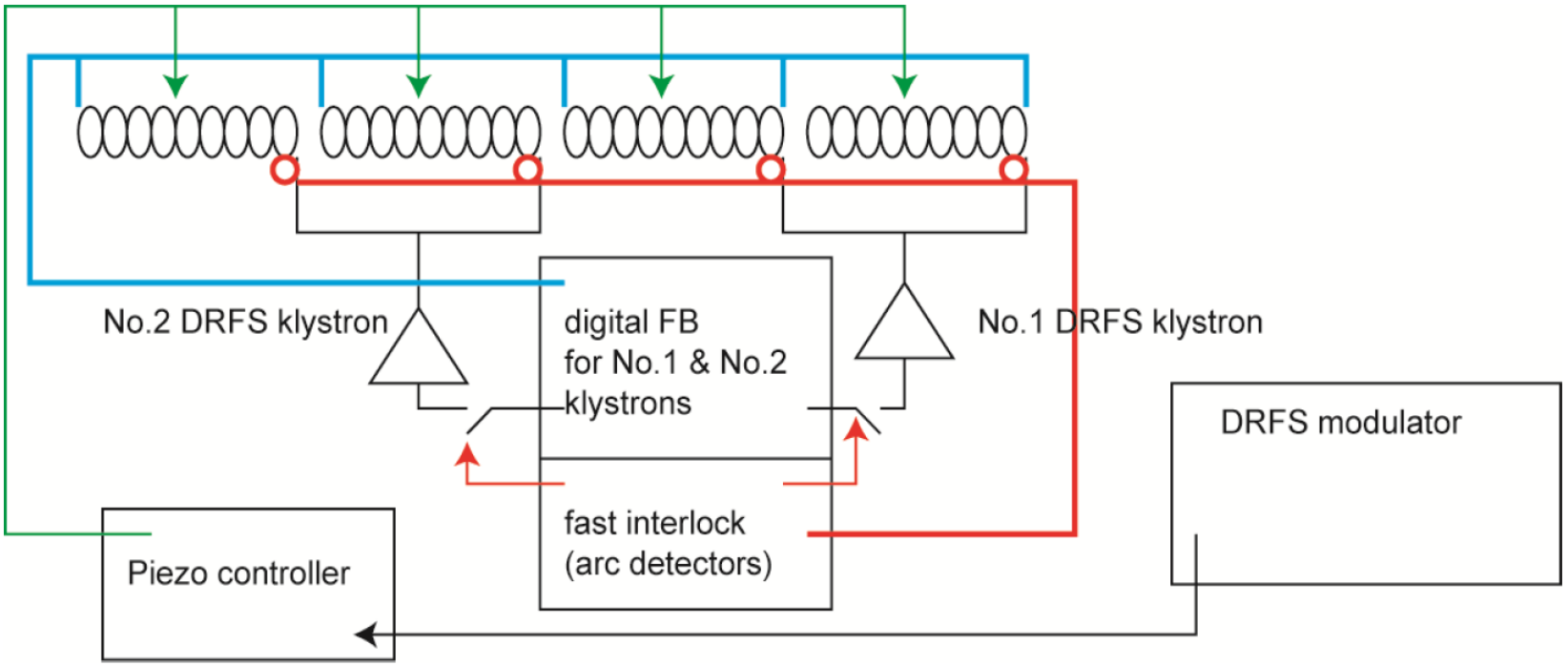
LLRF Program for S1 -Global

S1 Global 3rd stage (DRFS)

- New digital LLRF systems (uTCA) will be installed to the tunnel.
- Fast interlock will be also located at the tunnel.
- Piezo compensation from the ground level



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Fastinterlock performance

- ILC-aimed compact fast-interlock system will be installed to DRFS units.
- This was developed for J-PARC and was also installed to cERL rf test stand.

Study goal

- Performance evaluation

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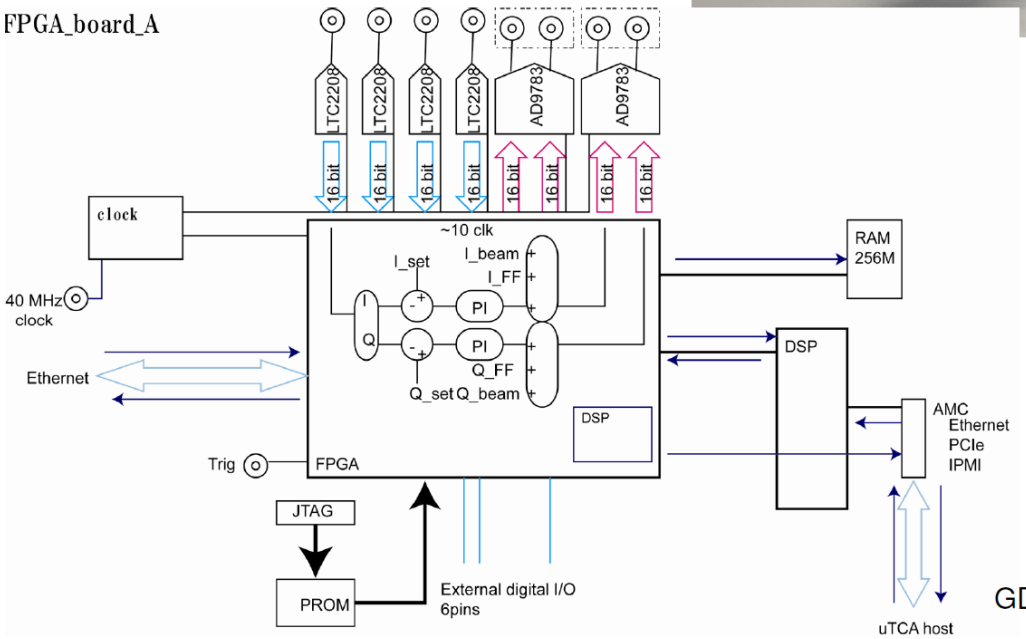
Field regulationField regulation

- cERL like uTCA FPGA system will be installed.

Study goal

- Performance evaluation



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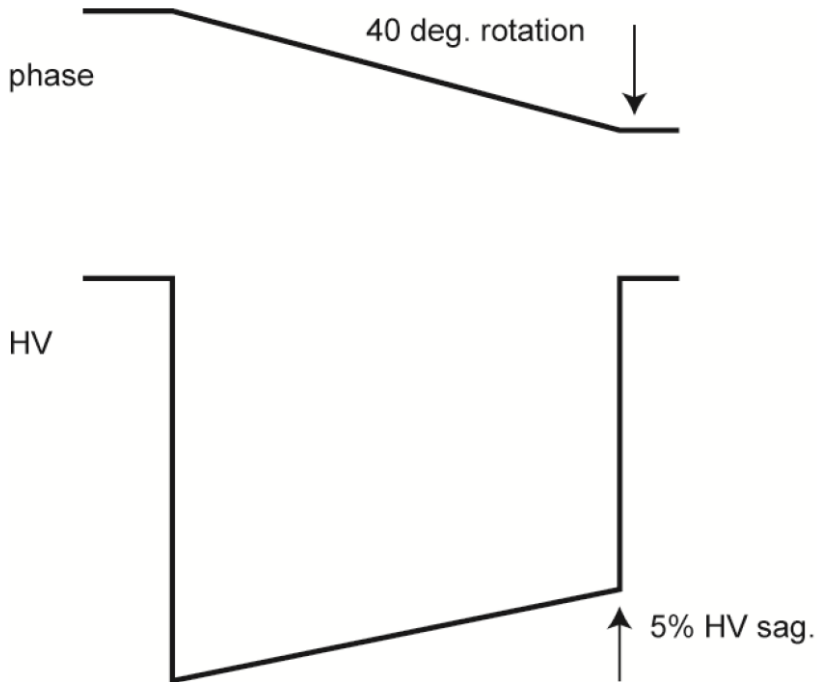
Sag compensation

- HV sag (~5%) will cause 40deg. Rotation. (8deg./%)
- This will degenerate the feedback stability and compensation is the essential for high feedback gain.

Study goal

- Proof of sag compensation



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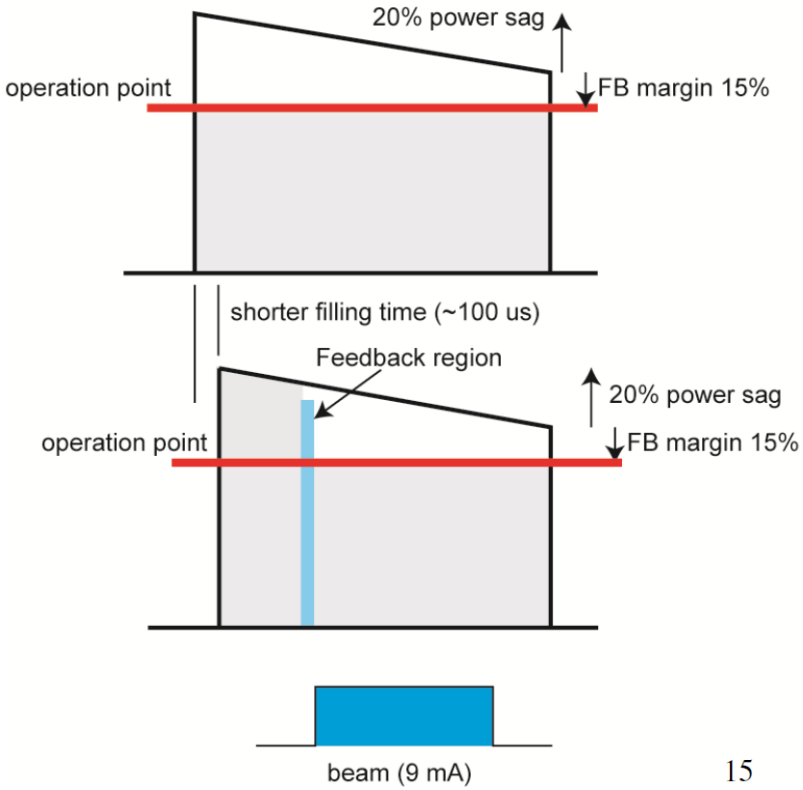
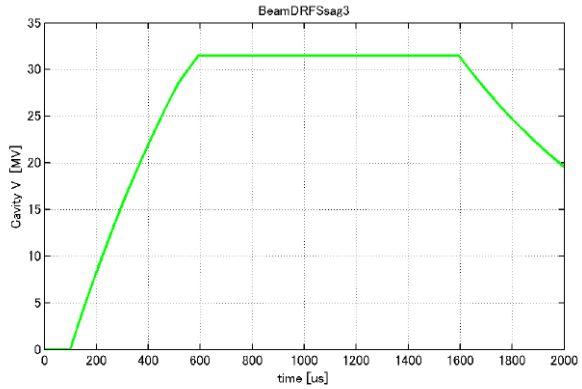
Full power filling scheme

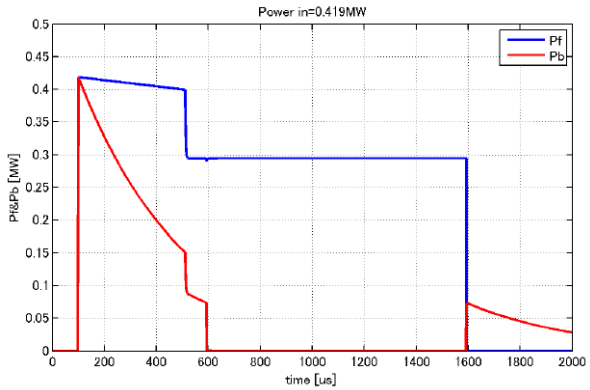
- In order to use the rf power under sag efficiently, full-power filling scheme is proposed.
- By using the full-power filling, shorter rf pulse will be enabled.

Study goal

- Proof of the scheme







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Circulator effects

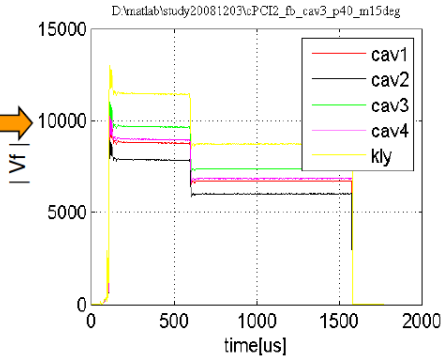
- The previous study (STF-1) indicate high isolation will be required at hybrid in order to estimate the cavity parameters (such as Ql and detuning).

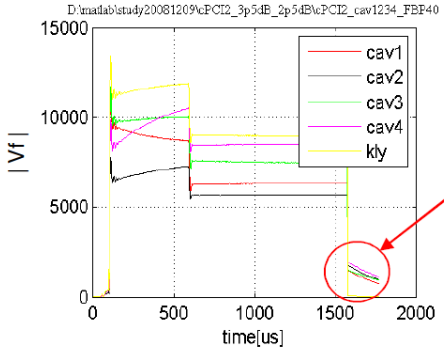
Study goal

- Study of the rf isolation with new hybrid system suitable for DRFS

With circulators ***Without circulators***

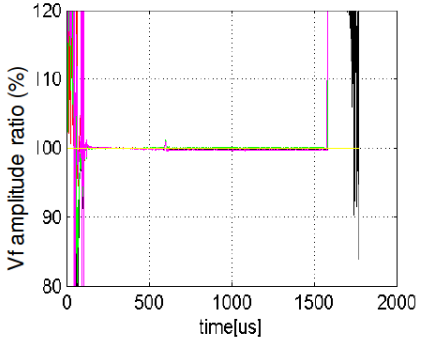
Cavity input

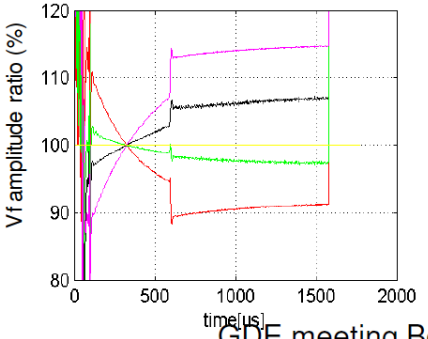




Cavity input exis
even after RF off

Normalized by klystron output





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HLRF R&D Issues

Follow-up plans (toward the "Quantum beam project" and STF-II)

- In KEK, successive test plans are follows up:
  - the "quantum beam project" in 2012 and STF-II plan in 2013.
  - RF system of the DRFS will be adopted in these successive test plans to demonstrate the basic function of DRFS.
  - In the "quantum beam project", one klystron of DRFS is used and LLRF feedback is performed with the beam.
  - In the first stage of the STF-II, 5 klystrons driven by a DC-power supply and a modulator feed powers to 10 cavities in an ILC-type cryomodule and in a "quantum beam" cryomodule with the beam operation.
  - LLRF digital feedback technology is conducted under the beam operation.
  - The FPGA board based on the micro-TCA will be installed and the vector sum control of two cavities in DRFS will be evaluated.

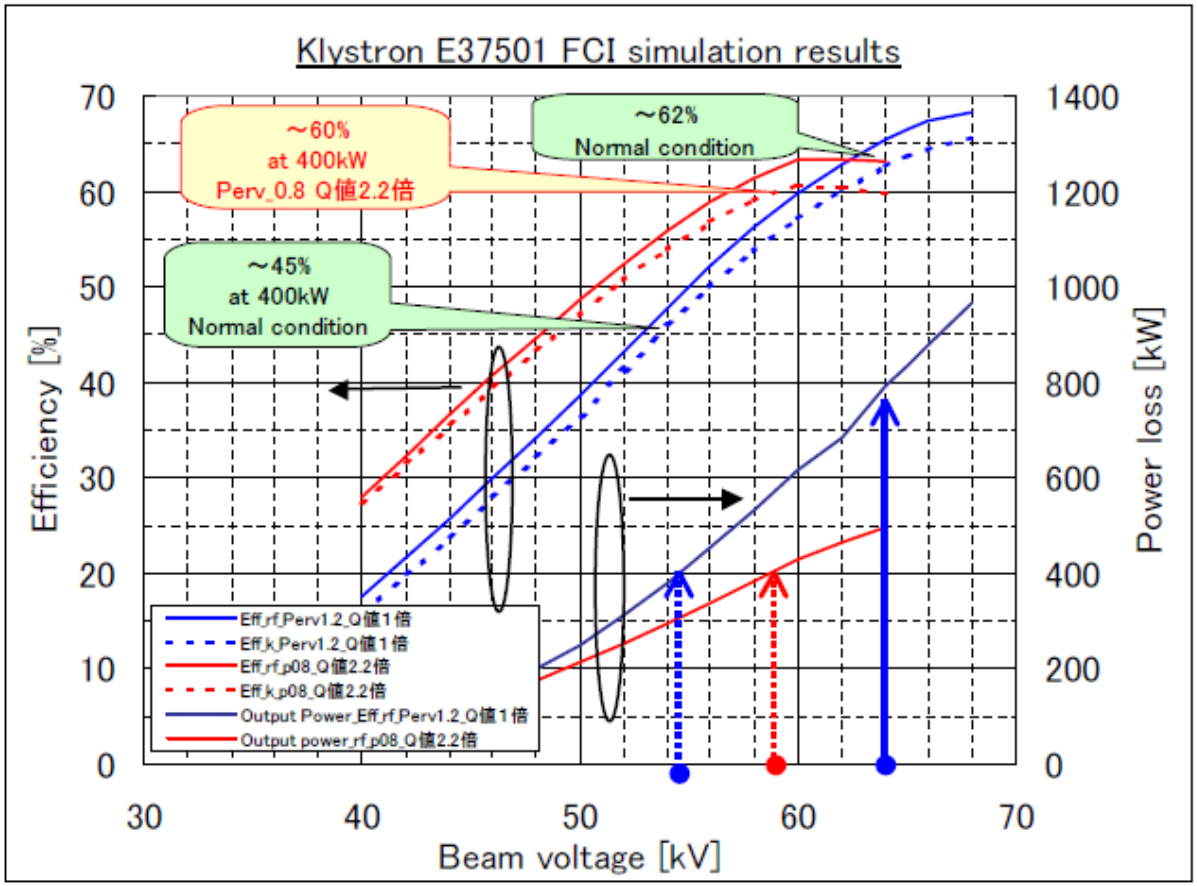
Test of Low-energy 10Hz Operation

Next Year in DRFS HLRF Test section

Confirm the prediction Of right simulation.

MA Modulator Modification

- Change the voltage ratio between K-MA and K-A.
- Insert simple iris in WG.



PS / NA Modulator R&D

- In the power supply and the MA modulator, important R&D items are,:
  - (1) development of reliable and cheep HV relay,
  - (2) the reliable and cheep gap switch for the crowbar circuit
  - (3) cheap large diameter current transformer or optically sensed current monitor.
- Though enough budgets for these R&D items are approved, it is necessary to have an effort to develop these R&D.
- We try to perform those minimum R&D through the plan of STF-II in three years.

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Summary

- We are now conducting S1-G testing, and though we have rf-source trouble, we continue to perform S1-G test successfully.
- DRFS-HLRF test is followed at the end of S1-G schedule.
- We have almost completed the hard-ware and LLRF field and they are shown in this presentation.
- This is the first opportunity to show the feasibility of DRFS system.