RF SYSTEM

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KEK

KEKB Machine Advisory Committee
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Outline

- Requirements
- (ARES cavity) ----- Talk was given by T. Kageyama
- (Superconducting cavity) ----- Talk was given by T. Furuya
- (Crab cavity) ----- Talk was given by K. Hosoyama
- Commissioning and upgrade
- Cavity choice
- System configuration
- High power system
- Low level RF system
- Crab RF system
- Conclusion

Requirements for the KEKB RF System

- Provide Accelerating Voltage (5-16 MV)
- Provide Beam Power (4 MW)
- Suppress C.B.I. arising from the accelerating mode
- Suppress C.B.I. arising from HOM's
- Control RF stably against heavy beam loading
  (Phase, Amplitude, Tuner, Bunch gap transient)

- Stable Operation
- Reduce Cost
- Use exsisting infrastructures and facilities as possible

RF-related Machine Parameters

	LER	HER	
Beam energy	3.5	8.0	GeV
Beam current	2.6	1.1	A
Bunch length	4	4	mm
Synchrotron tune	0.01 - 0.02	0.01 - 0.02	
RF voltage	4.9 - 9.4	8.7 - 16.2	MV
RF frequency	508.887		MHz
Energy damping time	43 / 23*	23	ms
Radiation power	2.1 / 4.0*	3.8	MW
HOM loss	0.57	0.14	MW
Total beam power	2.7 / 4.5*	4.0	MW

*with wigglers for LER

• Synchrotron tune is desired to be variable.

-----> RF voltage has not been definitely determined.

Commissioning and Upgrade

Construction of RF system will go in two phases:
(1) Commissioning (FY1998)
(2) High luminosity run ($L=10^{34}\ cm^{-2}s^{-1}$)

Commissioning:

- Provide necessary voltage to have
  - bunch length <10mm and
  - synchrotron tune > 0.01

----> Vc > 3 MV (LER), 6 MV (HER)

- 40-50 % of full beam current should be stored.

High luminosity run:

- Provide required voltage ----> 5-10MV(LER), 9-16MV(HER)
- Store full beam current

Cavity Choice (LER)

Parameters better fits ARES:

- Lower voltage and higher beam current in LER than HER.
- C.B.I. due to accelerating mode OK with ARES.
  (smaller detuning frequency of ARES)

-----> ARES will be used in LER.

Cavity Choice (HER)

Favorable points for SCC:

- C.B.I. due to accelerating mode OK in HER
- Refrigerator already available at Nikko
- Cost reduction
  (smaller number of cavities, less RF power)
- Experience in TRISTAN SCC

Unknown factors of SCC:

- No trips any more? Trip rate tolerable in KEKB?
  (Can we keep excellent vacuum condition in KEKB-SCC?)
  (AR test was 3.5GeV. OK with 8GeV beam?)
- Long-term stable operation with 1A beam
  (Stably operated in AR with 0.4A for 2 weeks. OK for longer period?)

Cavity Choice (HER), cont'd

Possible Choice for HER

(1) SCC (Nikko)
(2) SCC (Nikko) + ARES (Oho)
(3) ARES (Nikko + Oho)

Our strategy:

- At commissioning, we will have both SCC and ARES in HER: Either cavities can provide required voltage for the commissioning operation.

- For the high luminosity phase, we will choose one of the three above, based on results of commissioning operation.

Advantages of this strategy:

- We can test SCC for long-term period, operating for the commissioning.
- When SCC has some trouble, HER can be commissioned with ARES.
- Even if we choose the case (1) for high luminosity run, the ARES installed at Oho can be moved to Fuji for LER upgrading, so that they will not be wasted.

Number of Cavities

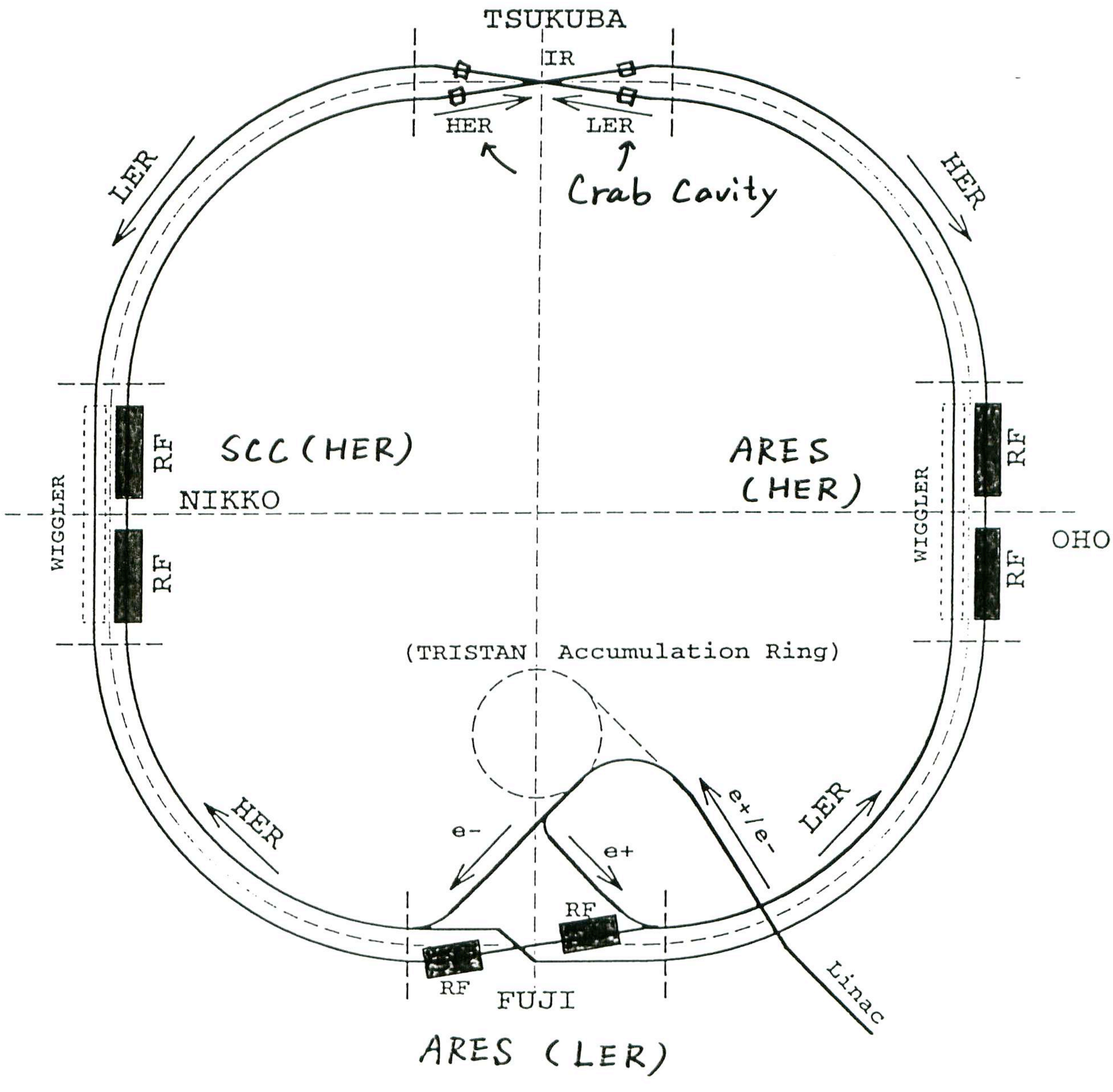
Ring	Station (cavity)	Commissioning	High Luminosity Run Nominal Vc (ν_s=0.015)	High Luminosity Run Maximum Vc (ν_s=0.02)
LER		Vc > 3 MV	7.5 MV	10 MV
	Fuji (ARES)	10	16-20	20-22
HER		Vc > 6 MV	12.5 MV	16 MV
case 1	Nikko (SCC)	-	10 SC	10-12 SC
case 2	Oho (ARES)	12-16	12	12
	Nikko (SCC)	4-5 SC	8 SC	10 SC
case 3	Oho (ARES)	-	20	20
	Nikko (ARES)	-	8	16

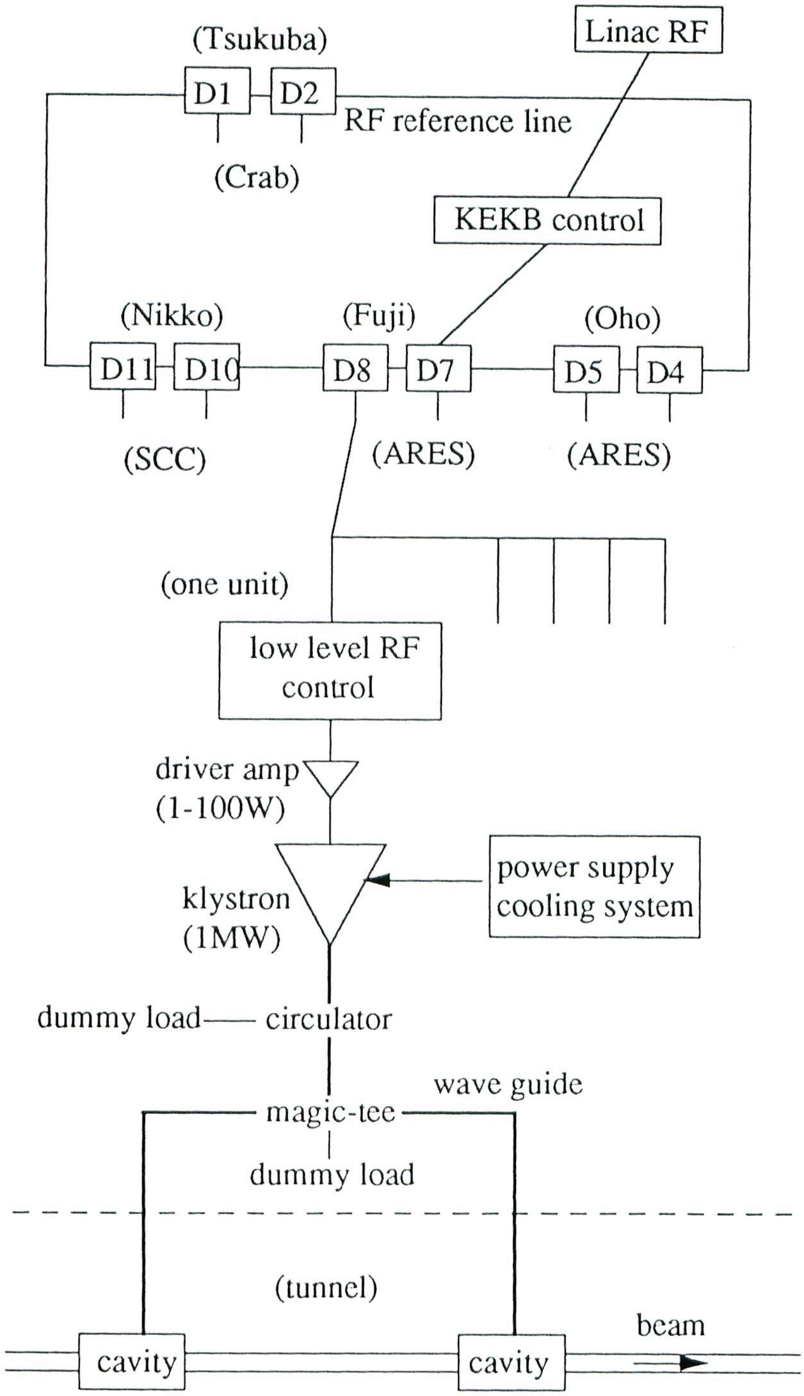
Example of RF Parameters

(for nominal Vc)

Ring		LER	HER	HER	HER
		w/wiggler	case 1	case 2	case 3
Cavity		ARES	SCC	SCC+ARES	ARES
RF voltage	MV	7.2	12.5	12.5	12.5
Number of cavities		18	10	8 + 8	28
R/Q	Ω	14.8	93	93 / 14.8	14.8
Q_0		1.1×10^5	$<1\times10^9$		1.1×10^5
Q_L ($\times10^4$)		2.4	5.0	6.2 / 2.4	3.5
Input coupling		3.6	-	- / 3.5	2.2
Cavity voltage	MV/cav.	0.4	1.25	1.2 / 0.4	0.45
Input power	kW/cav.	351	416	257 / 350	267
Wall loss	kW/cav.	98	-	- / 100	122
Beam power	kW/cav.	250	400	250 / 250	143
Detuning frequency	kHz	25.2	21.9		9.8
Growth time (acc.)	msec	13.4	38		145
Number of klystrons		9	10	8 / 4	14
Klystron power	kW	751	445	275 / 750	571

Location of RF stations in KEKB





Schematic view of the KEKB RF system

High Power System

Most of high power components that have been used in TRISTAN will be re-used in KEKB.

- 1 MW CW klystrons (Toshiba, Phillips)
- Power Supply for the klystrons
- RF Transmission system
  1MW circulators, magic tees, dummy loads, wave guides
- Cooling system

Advantage:

- Cost reduction
- Reliability and experience

They have been successfully operated in TRISTAN (~10 years).
~ 800 kW (32GeV), ~600 kW (29GeV).

High Power System (cont'd)

The number of RF units is about the same as TRISTAN.

(TRISTAN) 34

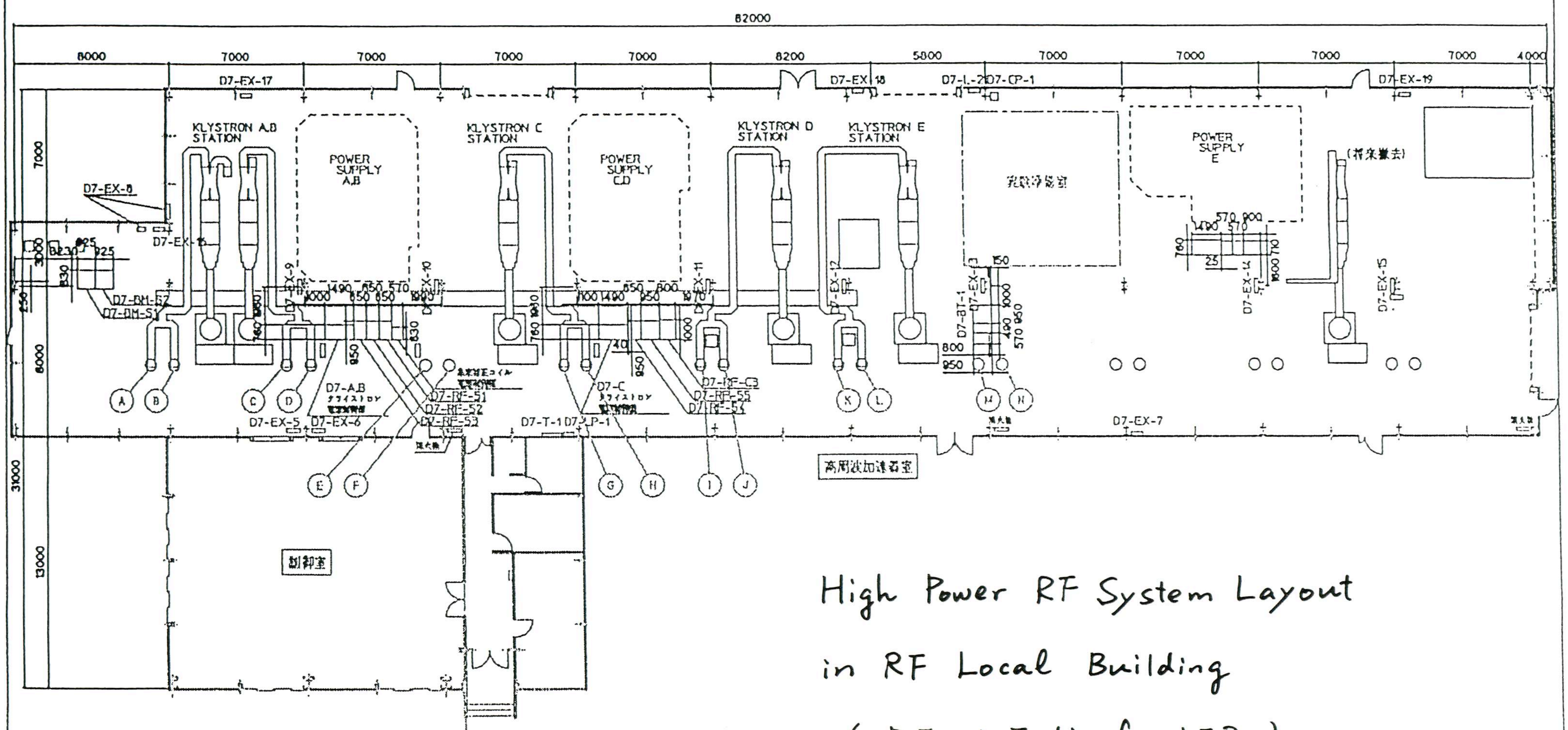
(KEKB) 10 (LER) + 10~18 (HER) + 4 (Crab) +4 (test stand)

New components to be installed:

- 1 MW dummy load for Magic-Tees (probably also for circulators)

Other issues:

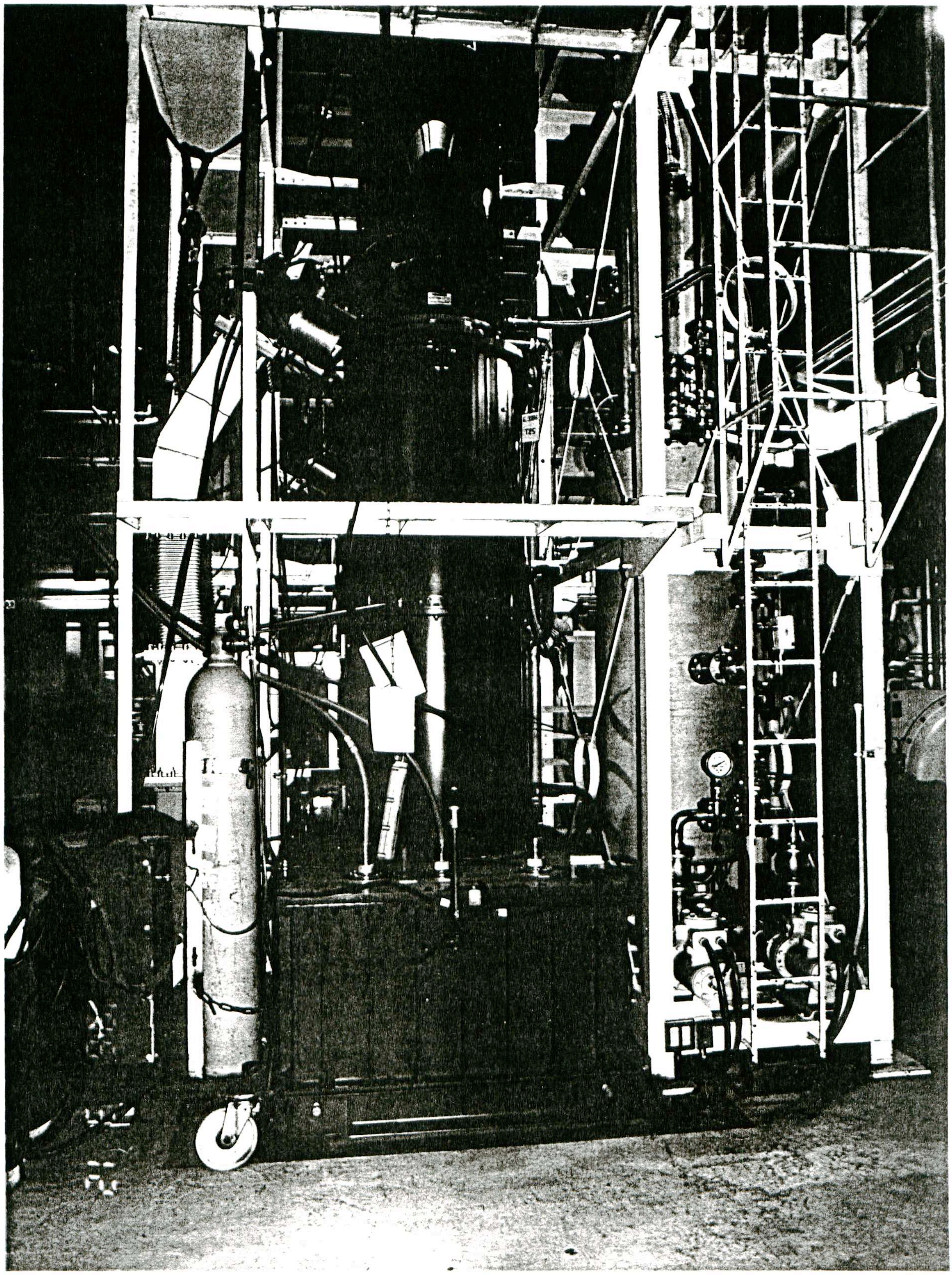
- Wave guide line stretchers will be used for ARES.
  (Wave guide length can be easily adjusted.)
- Distance between 2 ARES quarter wave length apart.
  (to prevent large reflection power from going into circulator)



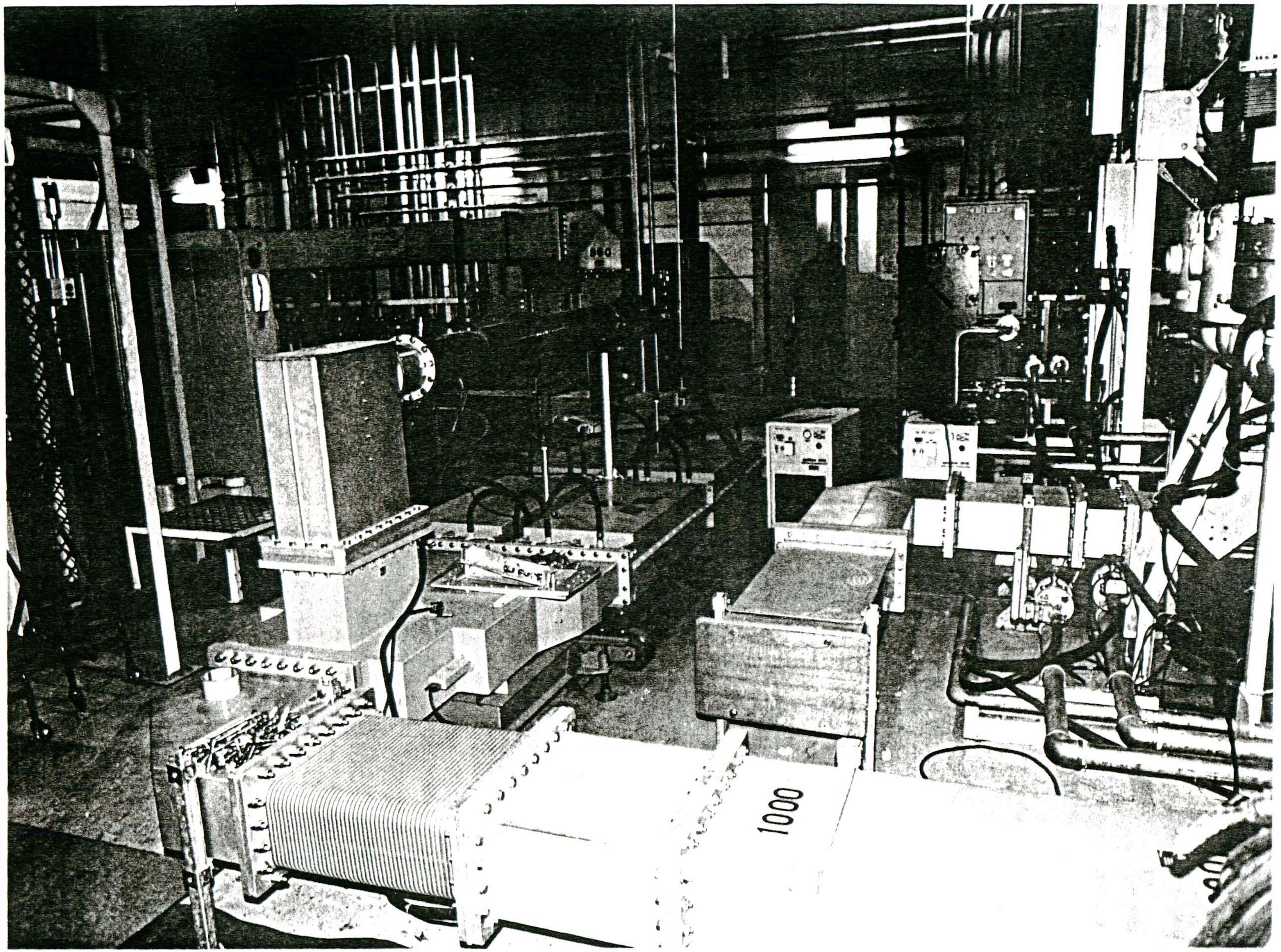
High Power RF System Layout

in RF Local Building

(D7 at Fuji for LER)



1 MW Klystron (Toshiba)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Low Level Control System

- Master Oscillator
- Timing system
- RF Reference line
- Low level RF control for ARES/SCC
  - Phase lock loop for cavity field
  - Phase lock loop for klystron
  - Amplitude control loop
  - Direct RF feedback loop (for accelerating mode stability)
  - Tuner control system
  - Interlocks
  - R&D of RF feedback using parallel comb filter (back up for -1, -2, --- modes instability)
  - Bunch gap transient
- Computer interface
- Operation software

RF Signal Flow in each RF unit with ARES

version 18Jan1997
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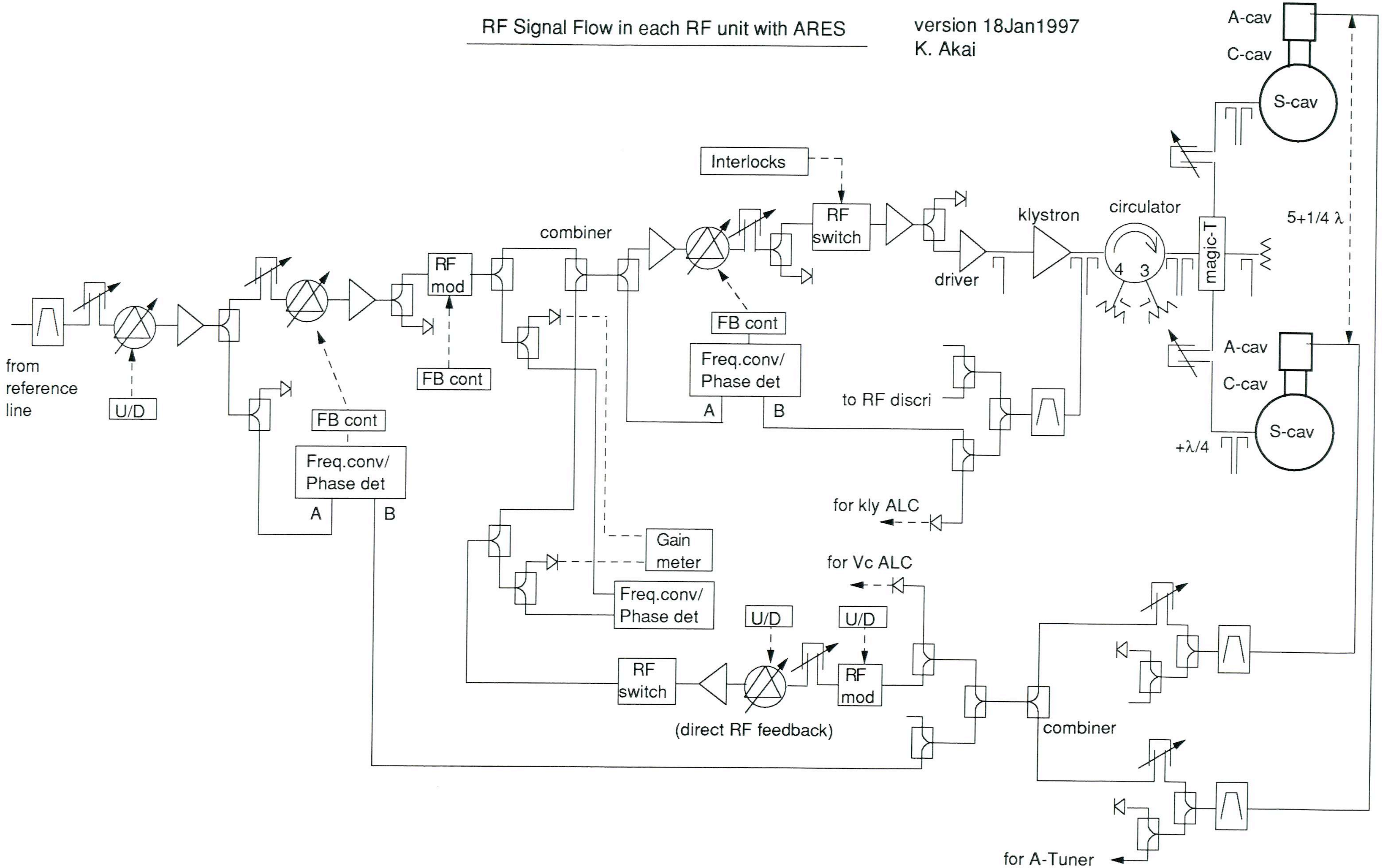

RF Signal Flow in each RF unit with SCC

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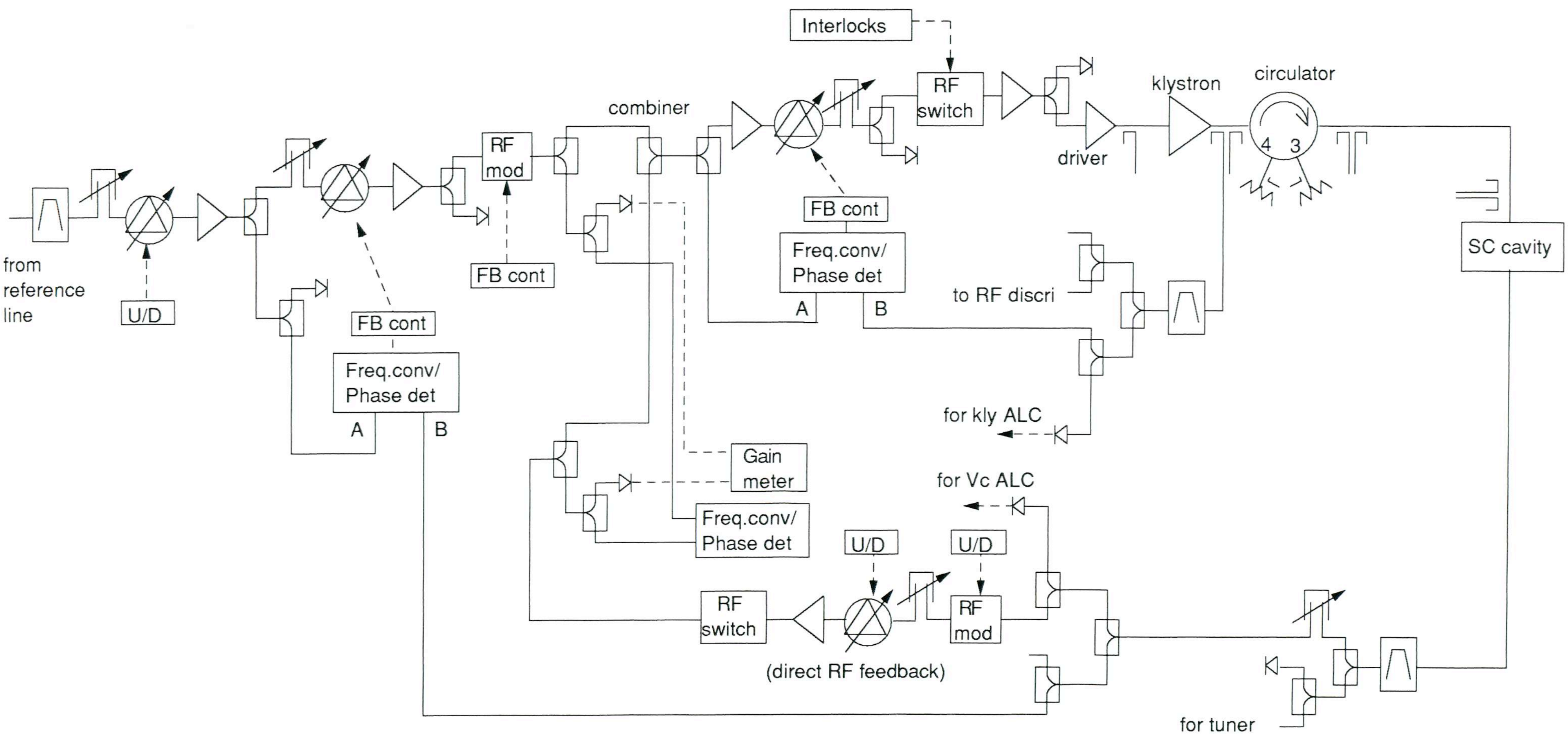
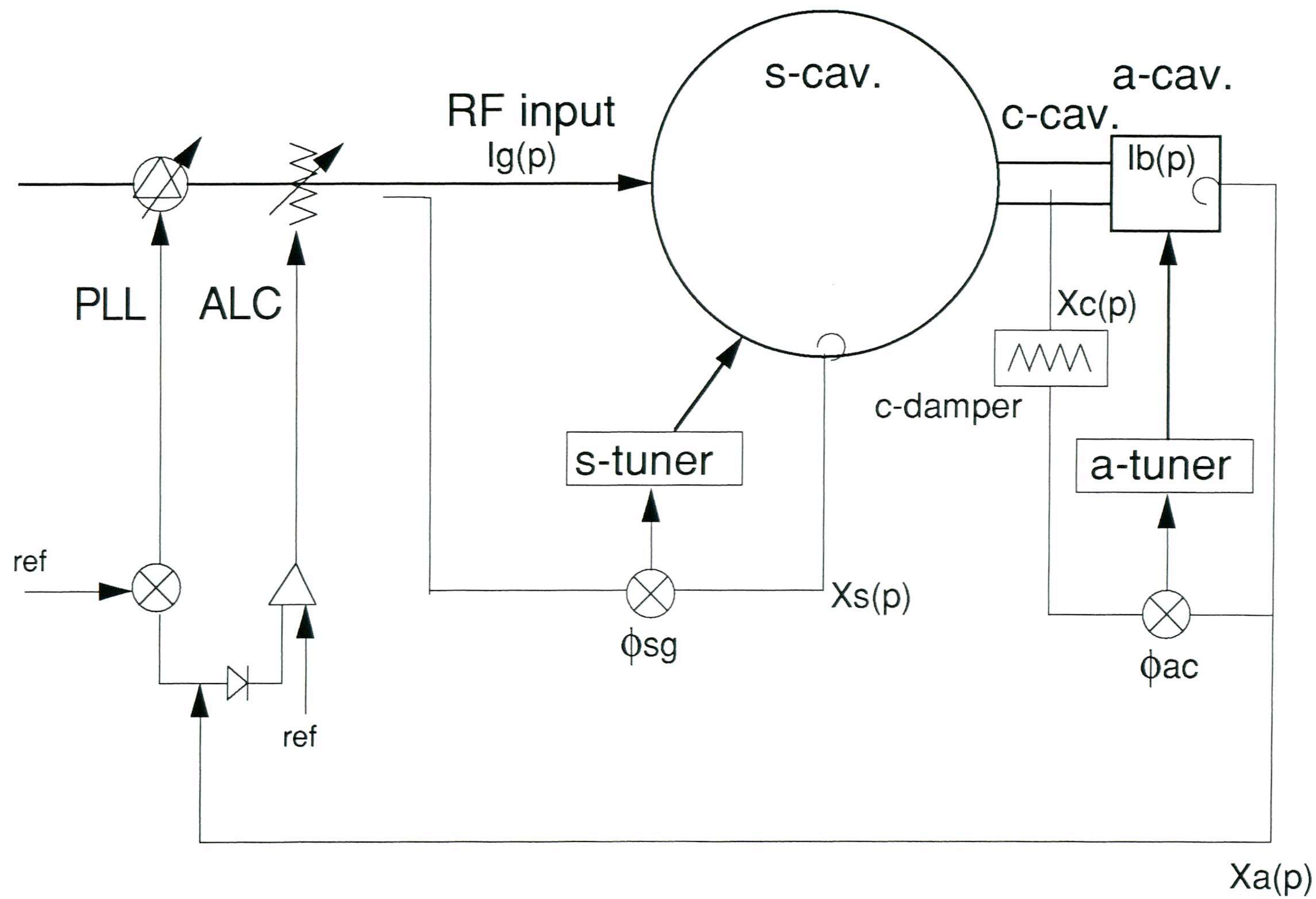




Block diagram of the tuning system for ARES

Beam Test of Direct RF Feedback in AR

Direct RF feedback system was tested in AR (operating SCC).
Results:

- Coherent synchrotron oscillation (0-mode) was effectively suppressed.
- Margin for static Robinson instability was improved.

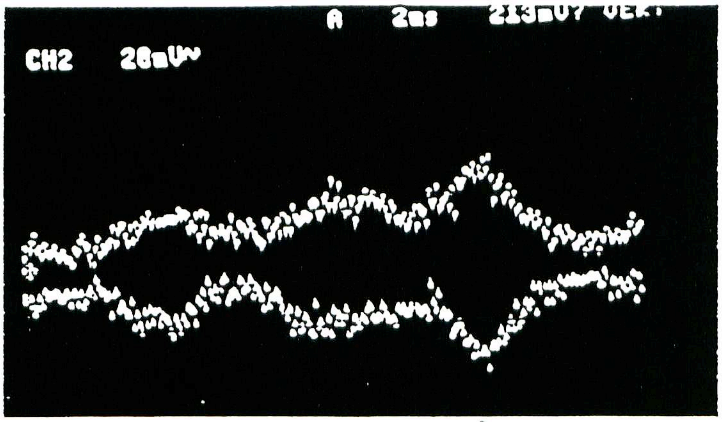
Beam Test of RF feedback using Parallel Comb Filter

RF feedback using parallel comb filter was tested in MR (APS cavities).
Results:

- -1 coupled-bunch mode oscillation was successfully damped.

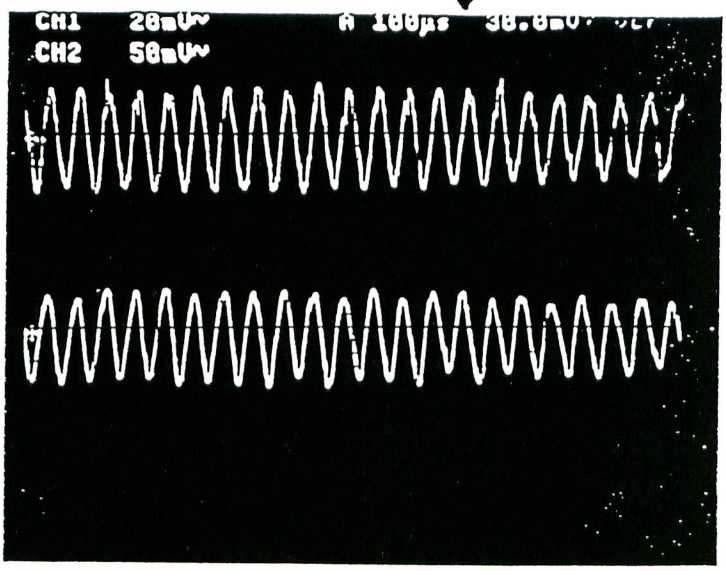
Effect of Direct RF Feedback

(400 mA, 16 bunches
SCC operated)



Envelope of Cavity Phase

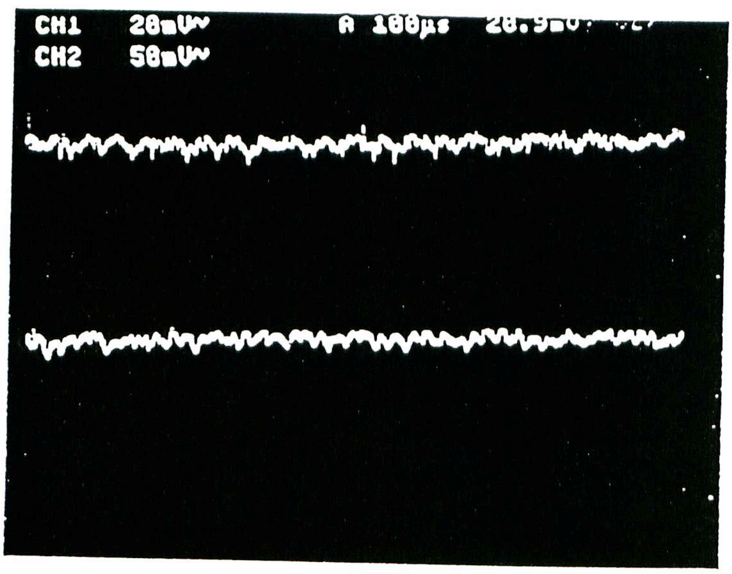
2 ms/div



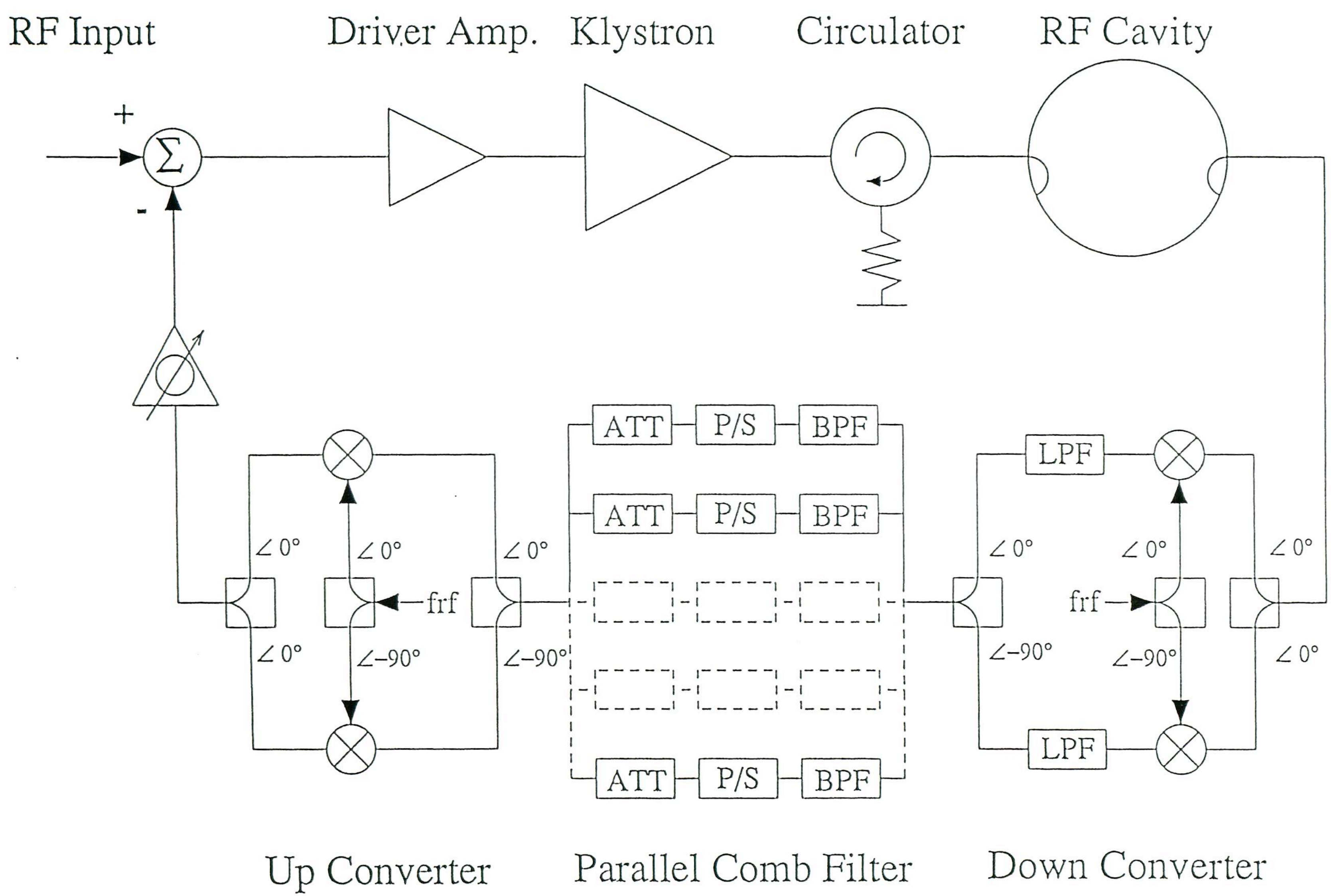
amplitude

phase ~1.4°

100 μs/div



← direct RF feedback ON



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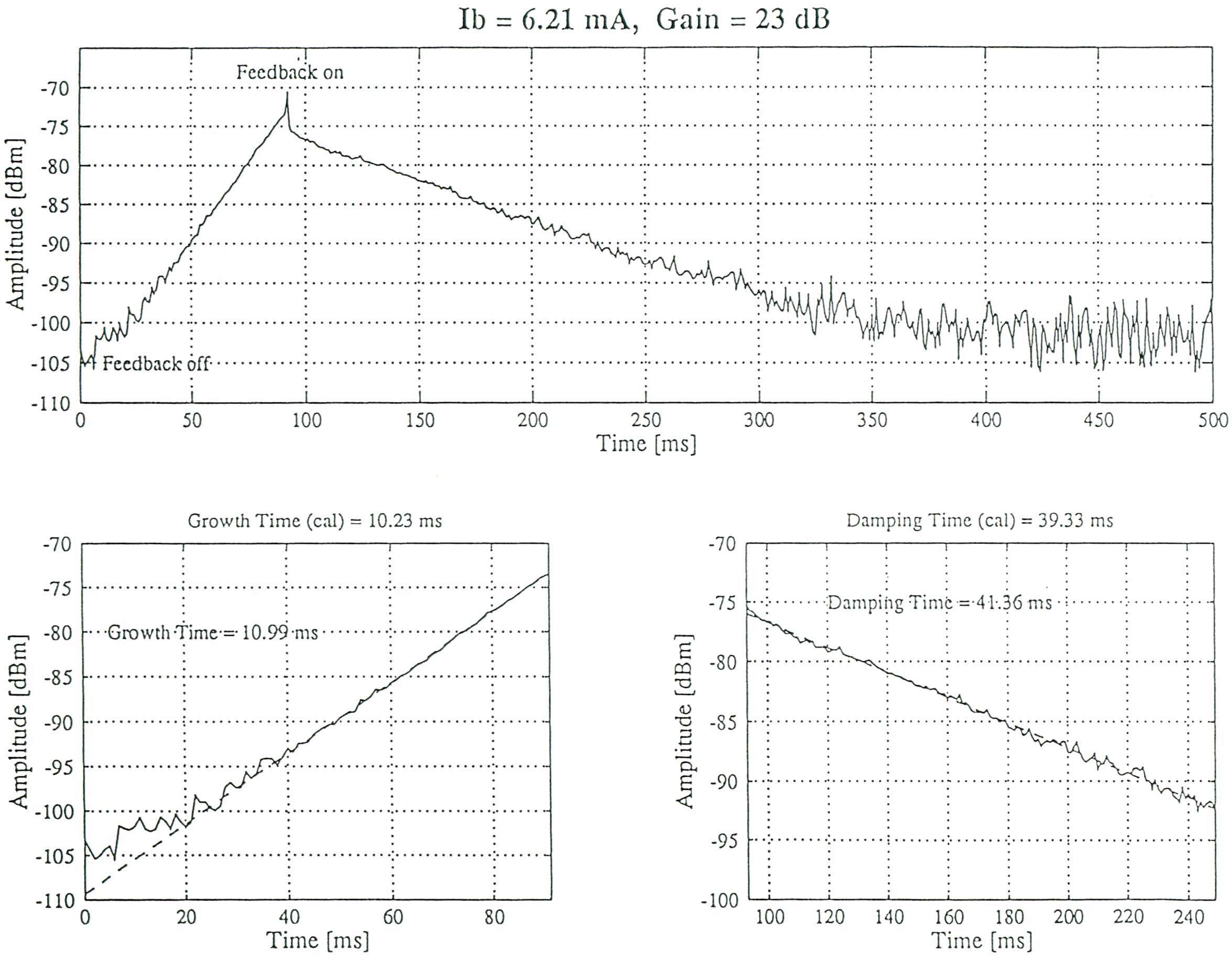
Block diagram of the RF-cavity feedback system using a parallel comb-filter.



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S. Yoshimoto

Measured amplitude of the −1 mode oscillation versus time
(Beam Test in MR)

Response to a Bunch Gap

An ion-clearing gap will be introduced in the HER. The bunch gap modulates the RF voltage.
Colliding point will shift bunch-by-bunch. (β^*_y=10mm,σ_z=4mm)

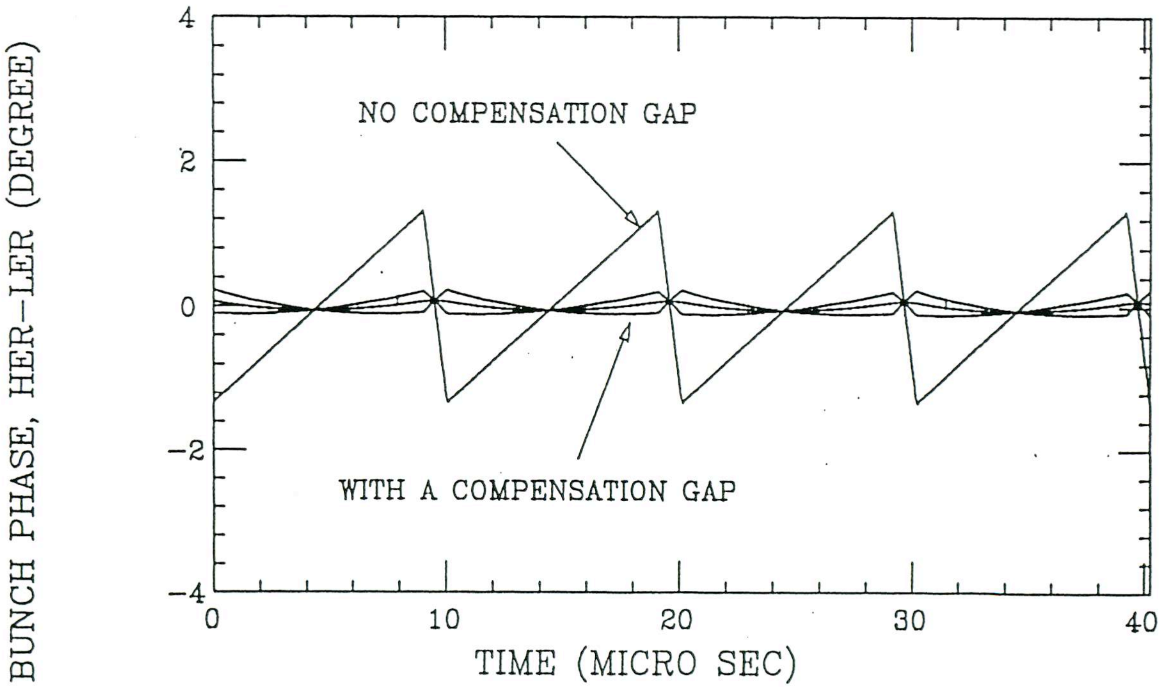
Cavity	gap length	bunch phase modulation (colliding point shift) with compensation gap? No	Yes
ARES	10%	2.7°p-p (±1.1mm)	~0.3°p-p (±0.1mm)
	5%	1.3°p-p (±0.5mm)	~0.1°p-p (±0.04mm)
SCC	10%	4.9°p-p (±2.0mm)	~0.5°p-p (±0.2mm)
	5%	2.4°p-p (±1.0mm)	~0.3°p-p (±0.1mm)

- The shift is small, owing to a large stored energy in ARES and SCC.
- The shift can be further reduced by the compensation gap.

EFFECT OF A COMPENSATION GAP IN LER (10% GAP)

HER, 1.1A, 20MV, 40ARES, I2/I1=0%

LER, 2.6A, 10MV, 20ARES, I2/I1=50%-60%, STEP=5%



Crab RF System

- Loaded-Q value of crab cavity will be 10^6. Requied input RF power is up to 50 kW, taking beam orbit displacement into account.
- We reserve 4 klystrons and 2 power supplies at Tsukuba for crab cavities.
- Required phase accuracy is 1 degree.
- Orbit displacement of $\pm$1mm in crab cavity is acceptable in view of power.

It is still desirable to control the orbit within $\pm$0.1mm for stable operation.

- RF Control system can be similar to that of SC accelerating cavity.

Conclusion

- Results of the AR beam test greatly encourages us to start mass production of ARES and SCC.

- Construction of RF system will go in two phases:
(1) Commissioning in FY1998 and (2) High luminosity run ($L=10^{34}$ $cm^{-2}s^{-1}$)

- ARES will be used in LER.

- At commissioning, both SCC and ARES will be operated in HER: Either cavities can provide required voltage for the commissioning operation.

- Most of high power components that have been used in TRISTAN will be re-used in KEKB.

- Low level control system has been conceptually designed. Controllability with heavy beam loading was successfully tested in AR.

- Crab RF system will be constructed in time for installation of crab cavity.