RF System for the Longtudinal Instability

(-1 Mode Damping at KEKB)

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Instability driven by the accelerating mode

Frequency detuning

$$\Delta f = \frac{I_0 \sin\phi_s}{2V_c}\left(\frac{R}{Q}\right)\times f_{rf} = \frac{P_b \tan\phi_s}{4\pi U} \tag{1}$$

Growth rate of the coupled-bunch instabilities

$$\alpha_\mu = \frac{e\alpha I_0 \omega_{rev}^2}{4\pi E_0 \omega_s}\sum_{m=1}^{\infty}\left\{(Mm - M + \mu)R_m^+ - (Mm - \mu)R_m^-\right\} - \frac{1}{\tau_s}$$

$$R_m^+ = \mathrm{Re}\,Z\left[(Mm - M + \mu)\omega_{rev} + \omega_s\right]$$

$$R_m^- = \mathrm{Re}\,Z\left[(Mm - \mu)\omega_{rev} - \omega_s\right] \tag{2}$$

How to cure the instability?

Completely different between the PEP-II and KEKB

◇PEP-II

Reduce the impedance seen by the beam using a combination of feedback loops.

◇KEKB

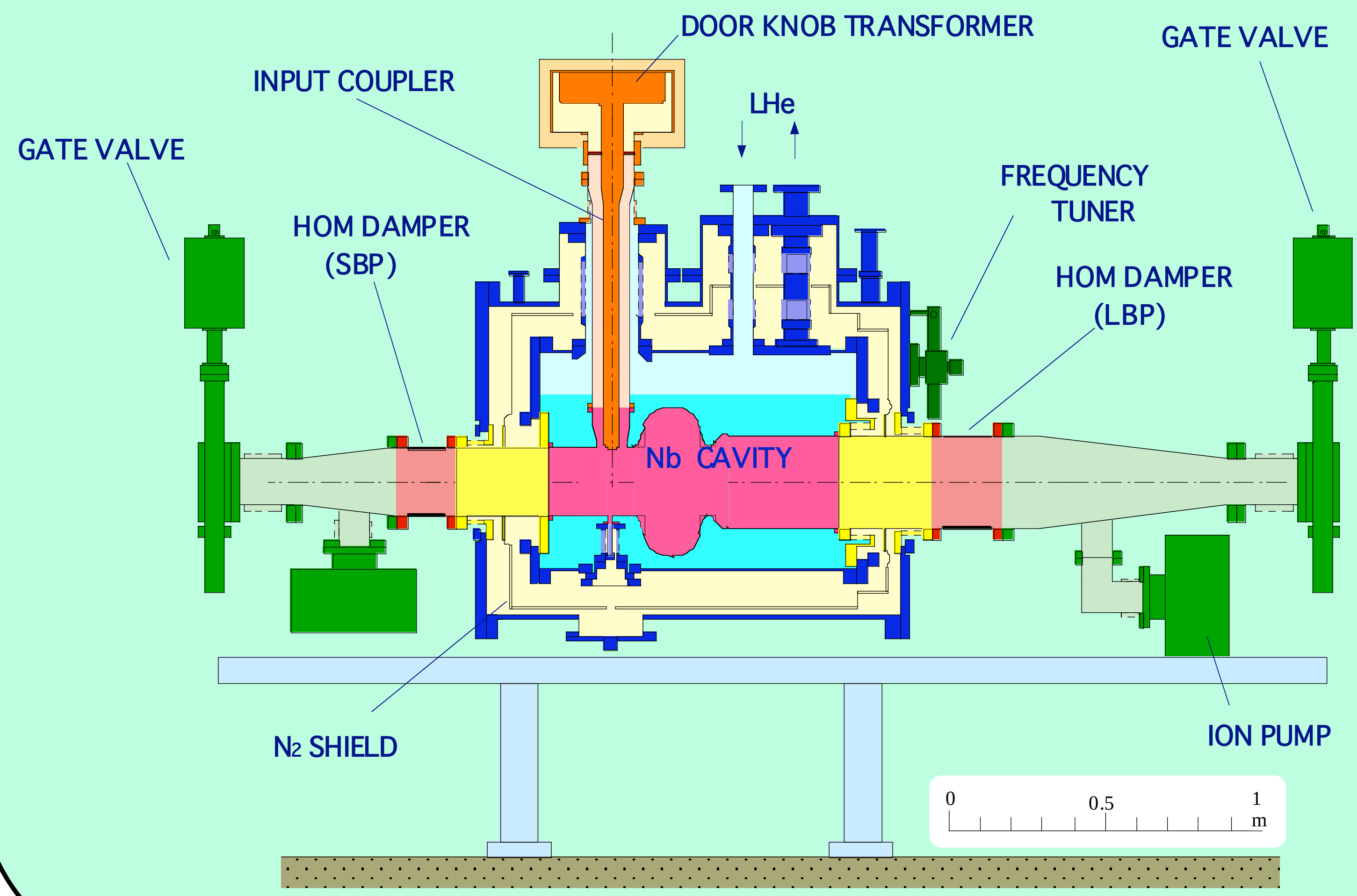
Reduce the detuning using high stored energy cavities

- ◇Super conducting cavity (high Vc operation)
- ◇ARES (**A**ccelerator **R**esonantly coupled with **E**nergy **S**torage)

$$\Delta f_{\pi/2} = \frac{U_a \Delta f_a + U_s \Delta f_s}{U_a + U_s} = \frac{U_a}{U_a + U_s} \Delta f_a = \frac{\Delta f_a}{10} \quad (\because U_a : U_s = 1:9)$$

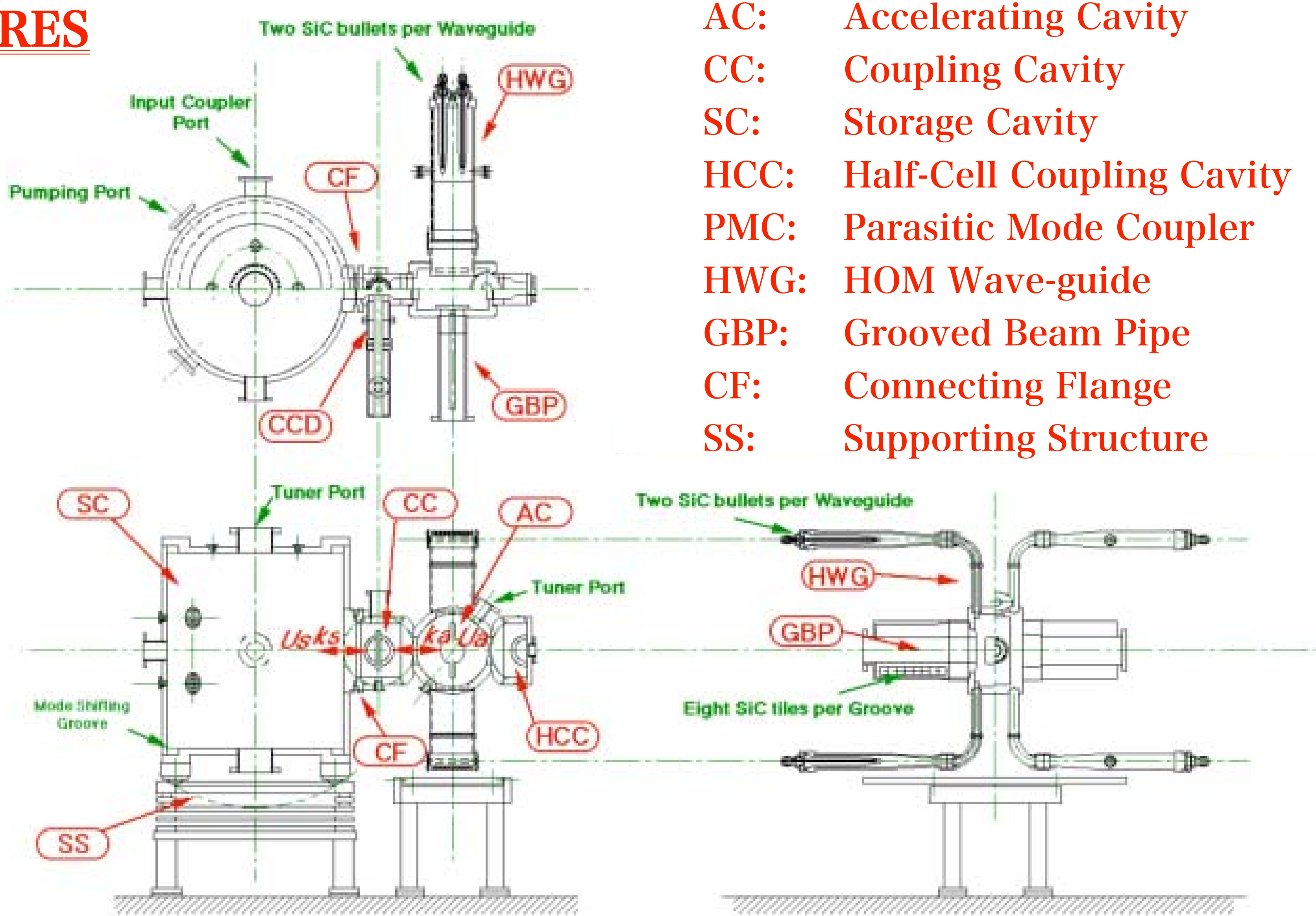
How to cure the instability? (cont'd)

SCC



How to cure the instability? (cont'd)

ARES



AC: Accelerating Cavity
CC: Coupling Cavity
SC: Storage Cavity
HCC: Half-Cell Coupling Cavity
PMC: Parasitic Mode Coupler
HWG: HOM Wave-guide
GBP: Grooved Beam Pipe
CF: Connecting Flange
SS: Supporting Structure

Is the feedback necessary for KEKB ?

Achieved and design rf-related parameters

	LER	HER	
Beam Energy [GeV]	3.5	8.0	
Beam Current [A]	1.65 (2.6)	1.0 (1.1)	
Momentum compaction ($\times 10^{-4}$)	3.41	3.38	
RF frequency [MHz]	508.887	508.887	
Energy loss/turn [MeV]	1.64	3.48	
Total RF voltage [MV]	8 (10)	13 (17.9)	
Synchrotron tune	-0.0249	-0.0208	
Cavity type	ARES	ARES	SCC
Number of Cavities	20	10 (12)	8
Cavity voltage [MV/cav]	0.4 (0.5)	0.29 (0.5)	1.25 (1.5)
R/Q [Ω]	15	15	93
Loaded Q ($\times 10^{4}$)	3.0	3.0	7.0

Numbers in ( ) are design values.

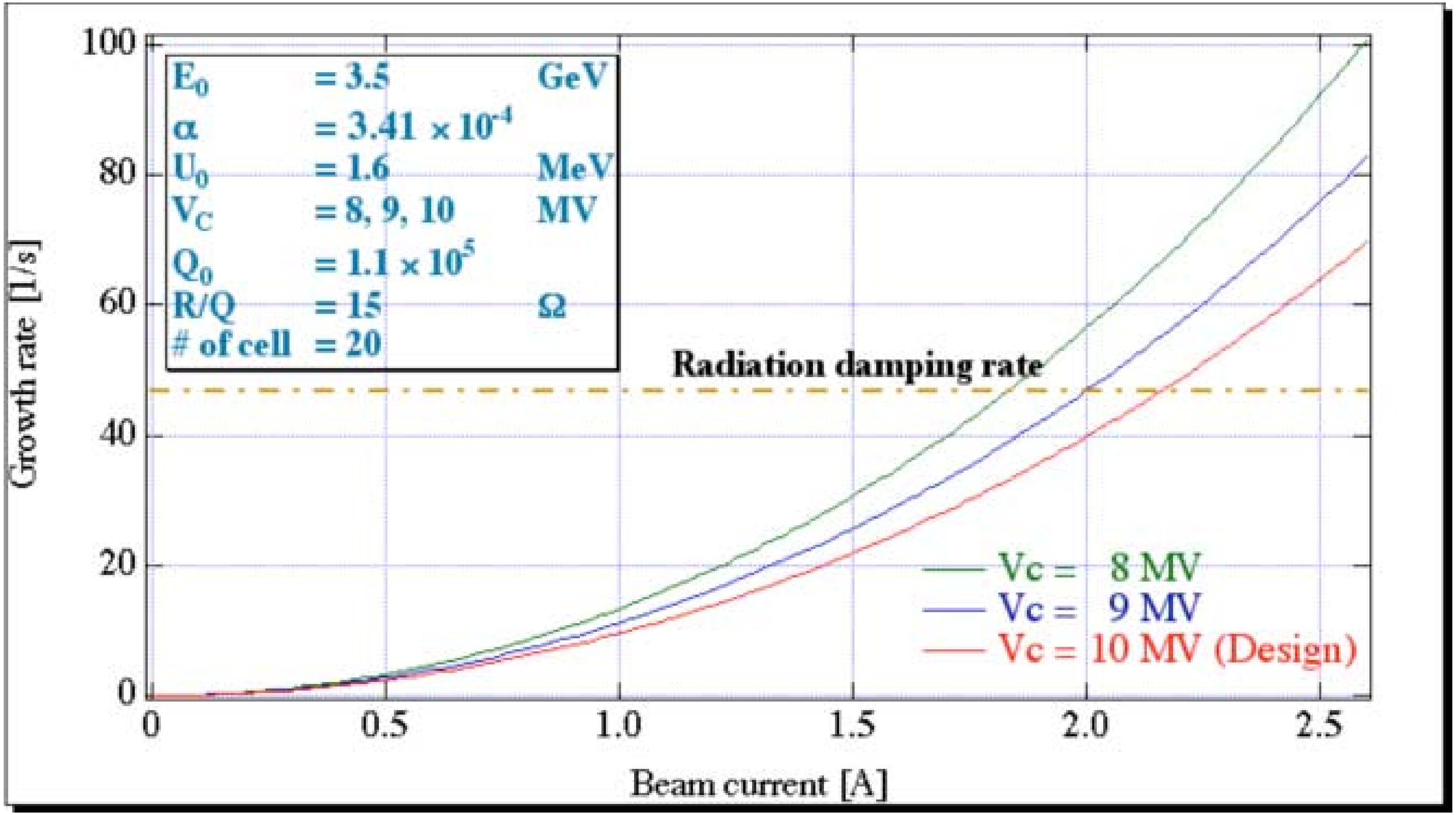
Is the feedback necessary for KEKB ? (cont'd)

- KEKB
  - HER: No, LER: Yes (LER current > 2 A)
  - The -1 mode is not sufficiently suppressed only by the ARES scheme.

- Super KEKB
  - Yes, of course.
  - LER current : 2.6 A -> 9.4 A
  - Detuning freq. : 20 kHz -> 71 kHz
  - Not only the -1 mode but also the -2, -3 mode

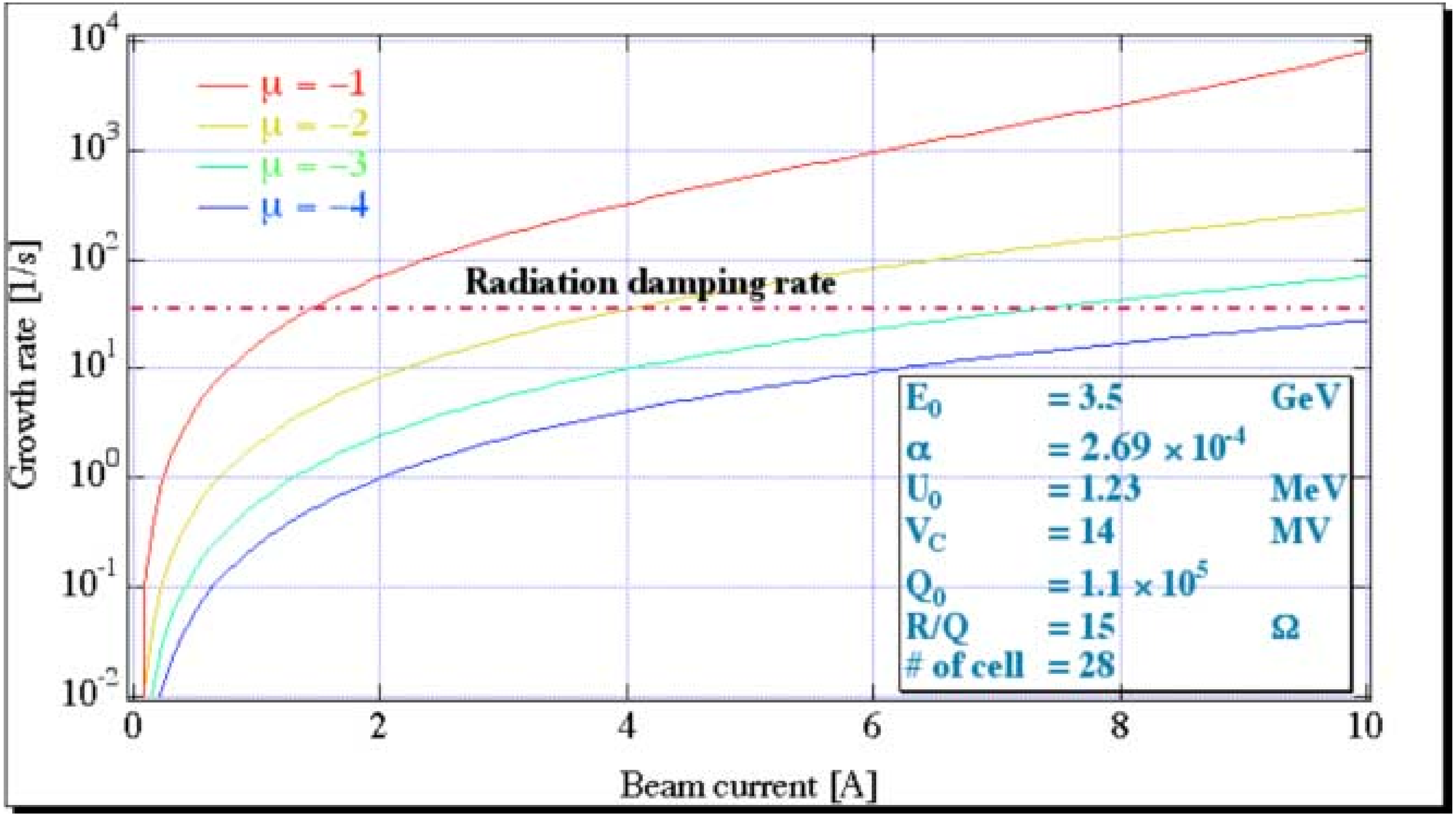
Is the feedback necessary for KEKB ? (cont'd)

Growth rate of the -1 mode in LER (KEKB)

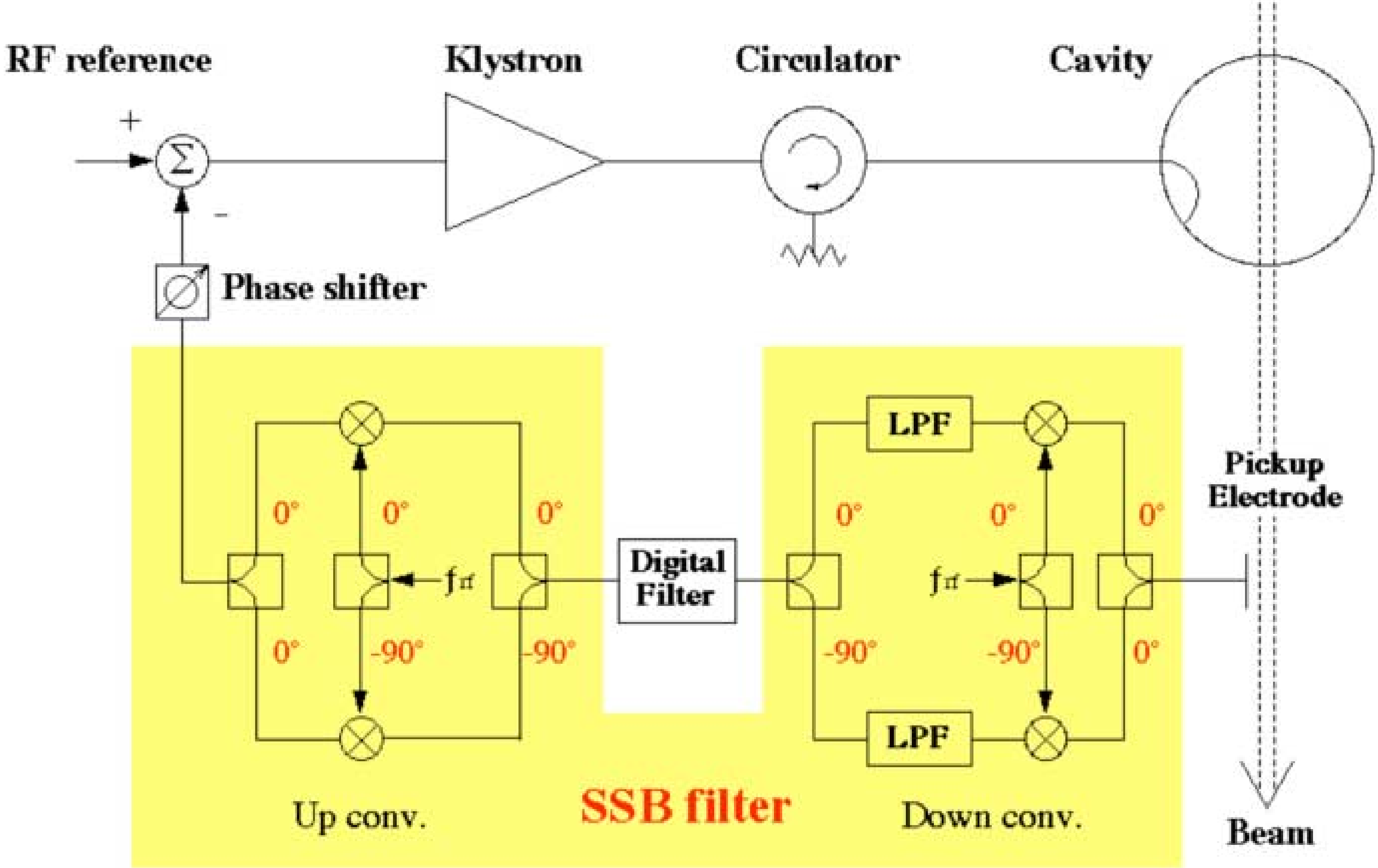


Is the feedback necessary for KEKB ? (cont'd)

Growth rate of the CBI in LER (Super KEKB)

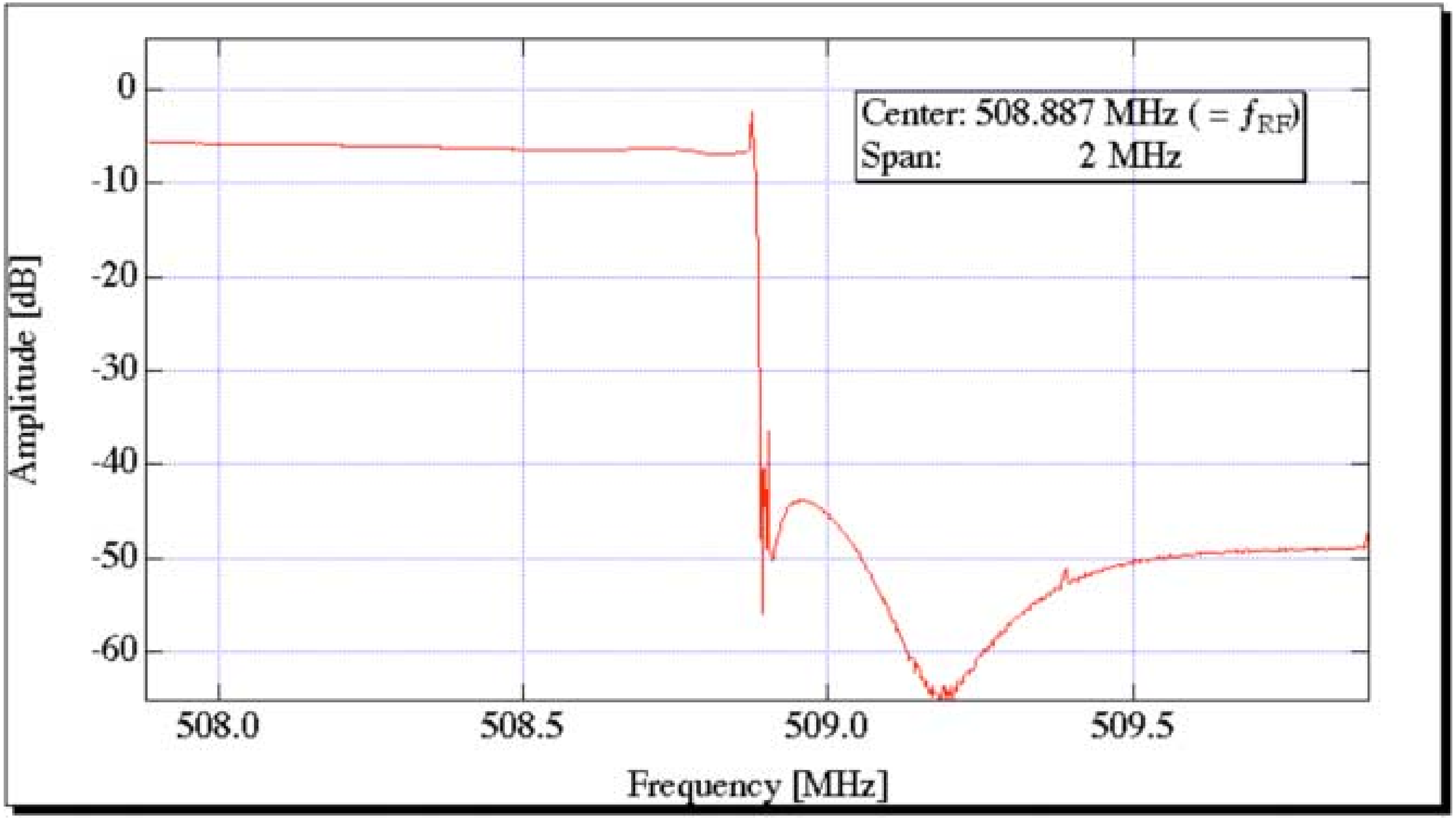


-1 mode damping system at KEKB



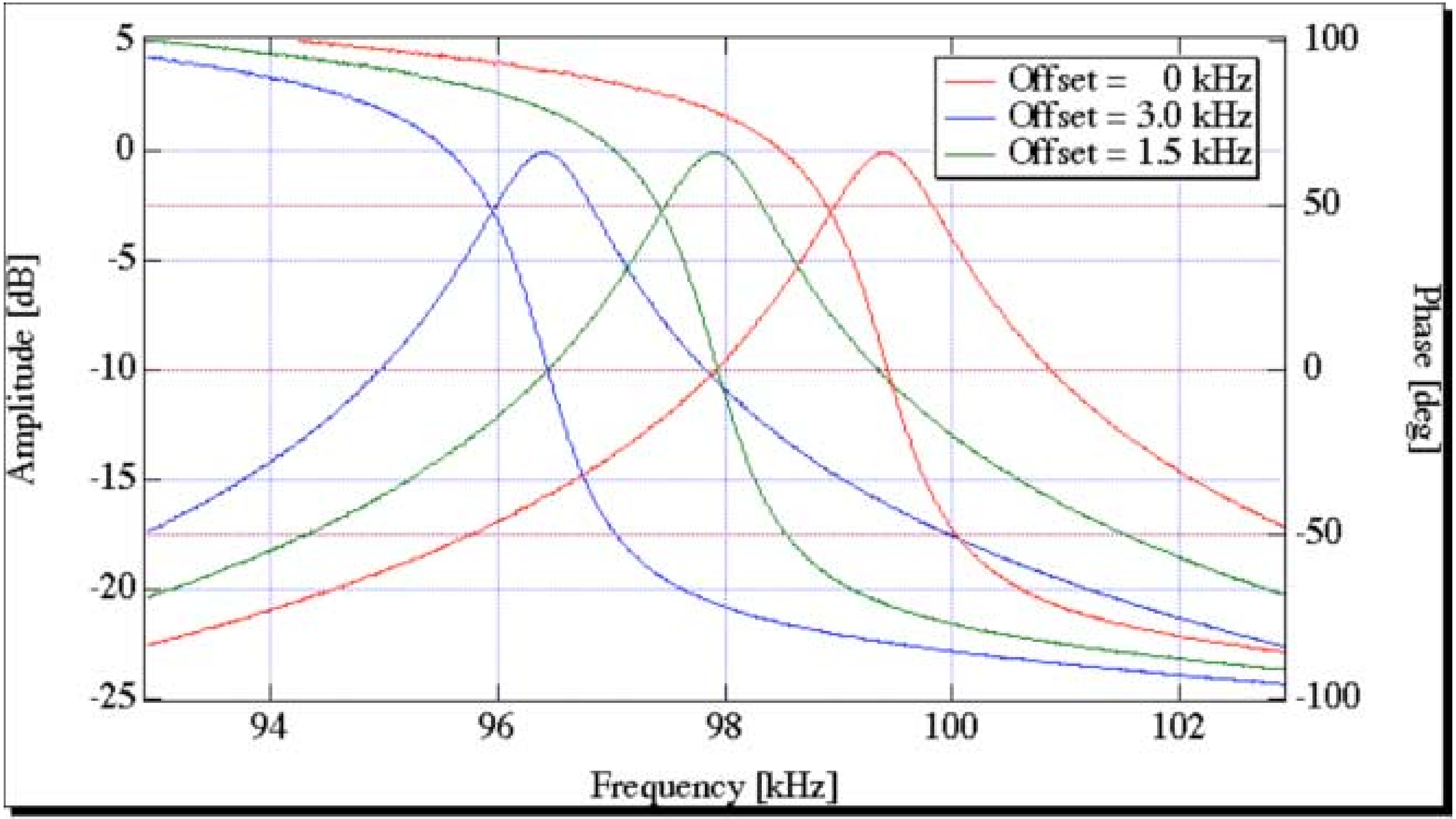
-1 mode damping system at KEKB (cont'd)

Measured transfer function of the SSB filter



-1 mode damping system at KEKB (cont'd)

Measured transfer function of the digital filter



Beam test results in LER

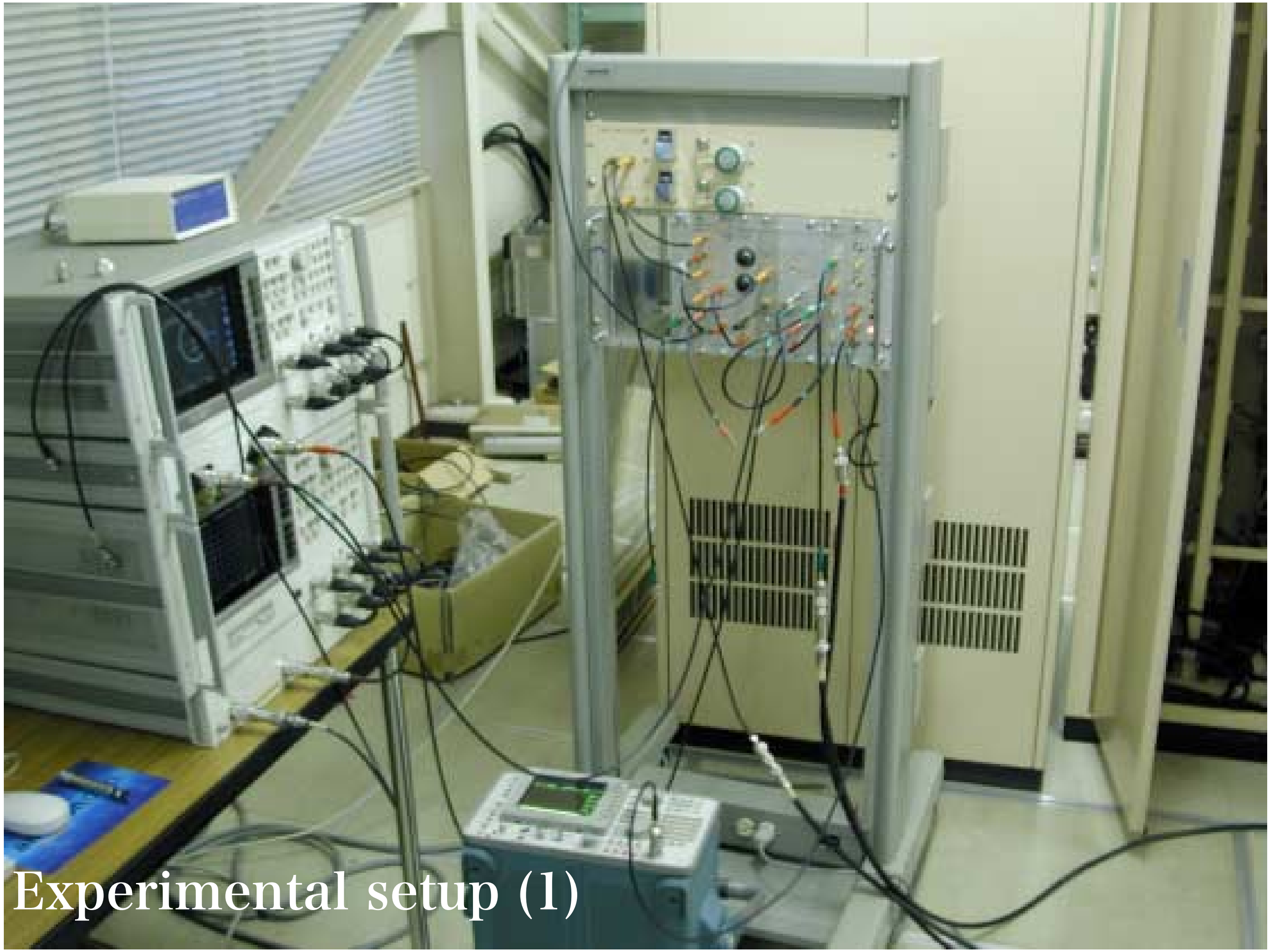
How to excite the instability ?

- Intentionally detuning two ARES cavities (one RF station)
- The frequency detuning is about -60 kHz

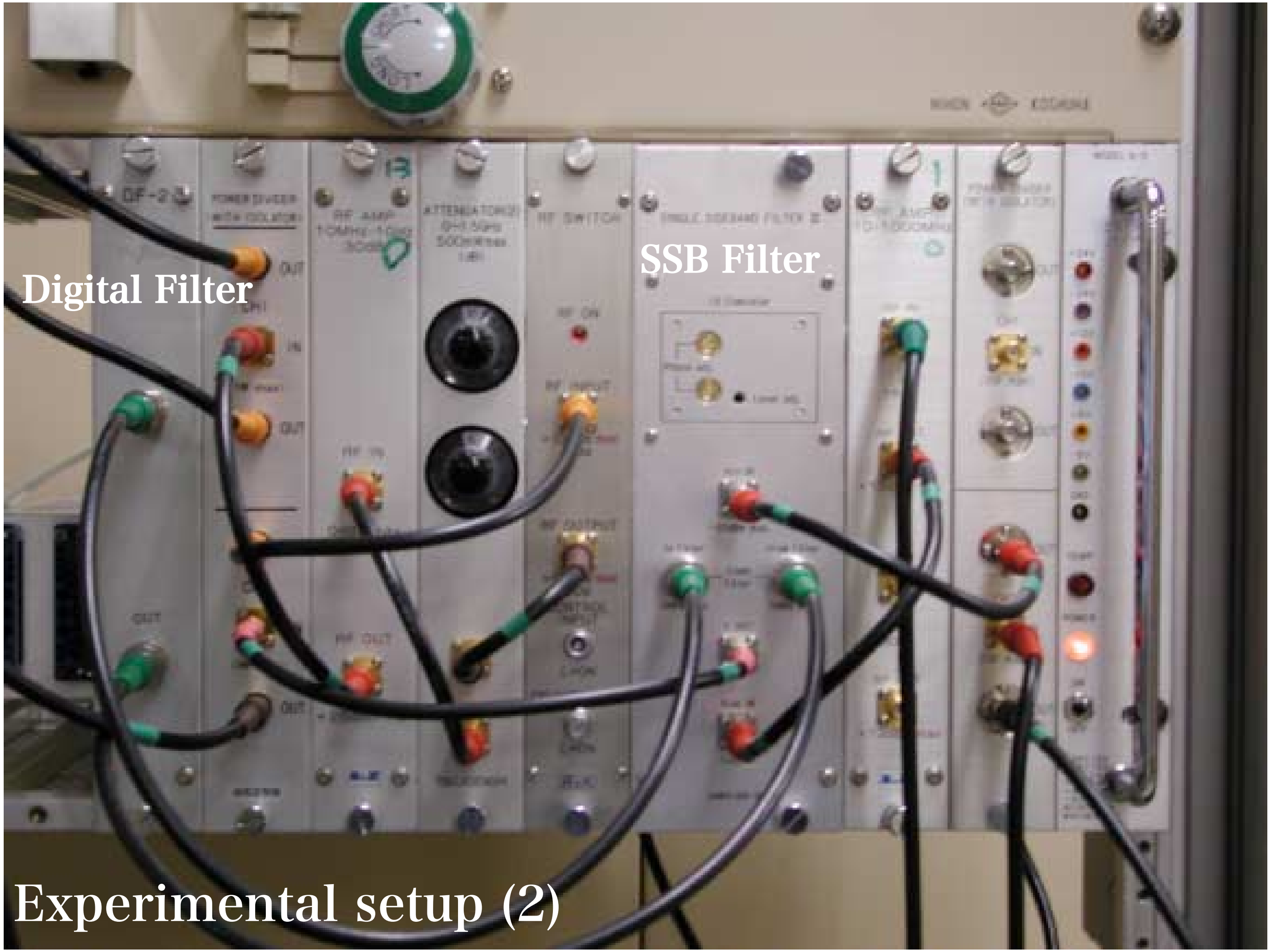
Experimenral procedure

1. measure the f_s by the spectrum analyzer.
2. adjust the center frequency of the filter to the synchrotron upper sideband (-1 mode).
3. adjust the phase using the phase shifter by observing the spectrum of -1 mode.

Beam test results in LER (cont'd)

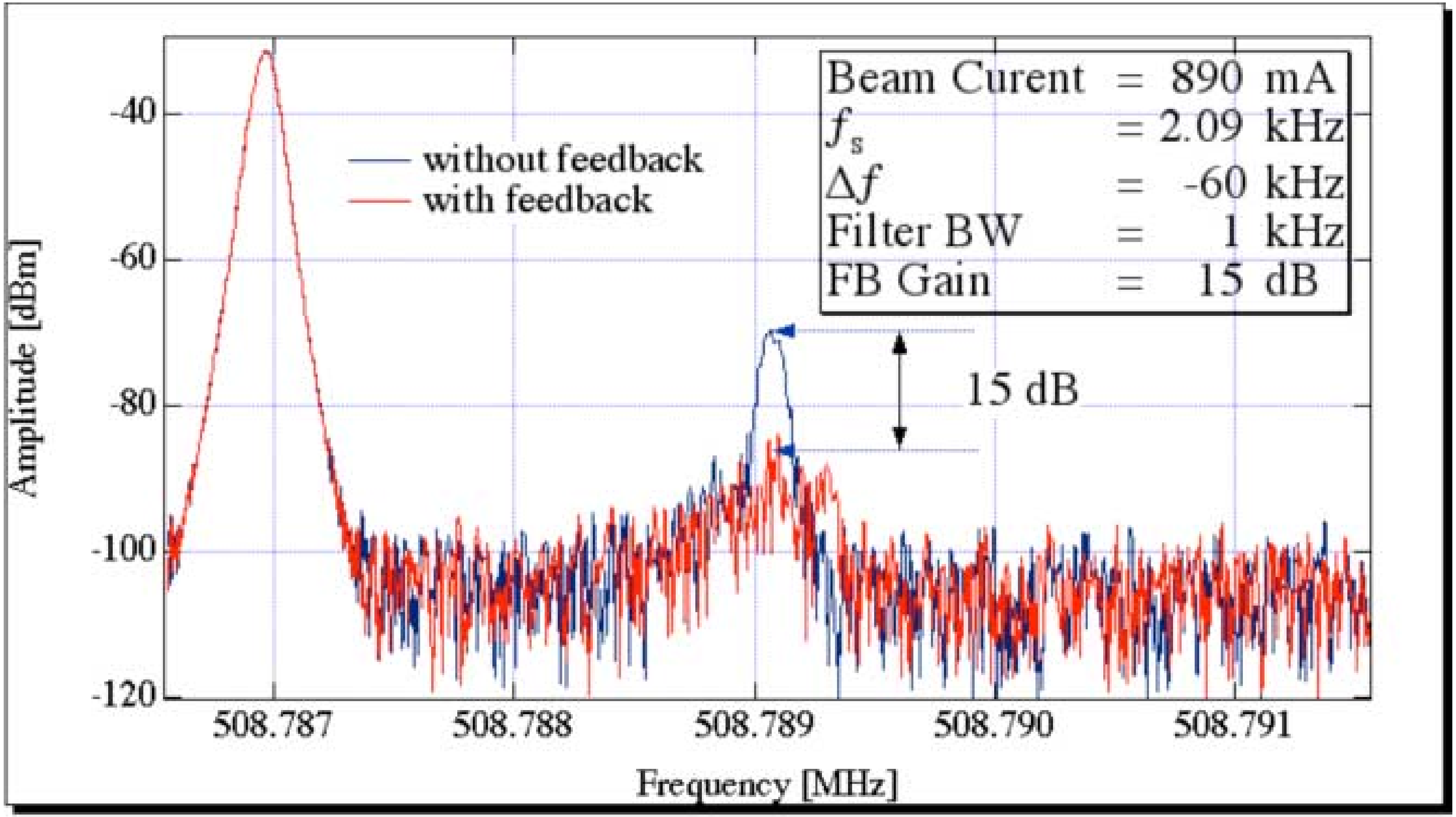


Beam test results in LER (cont'd)



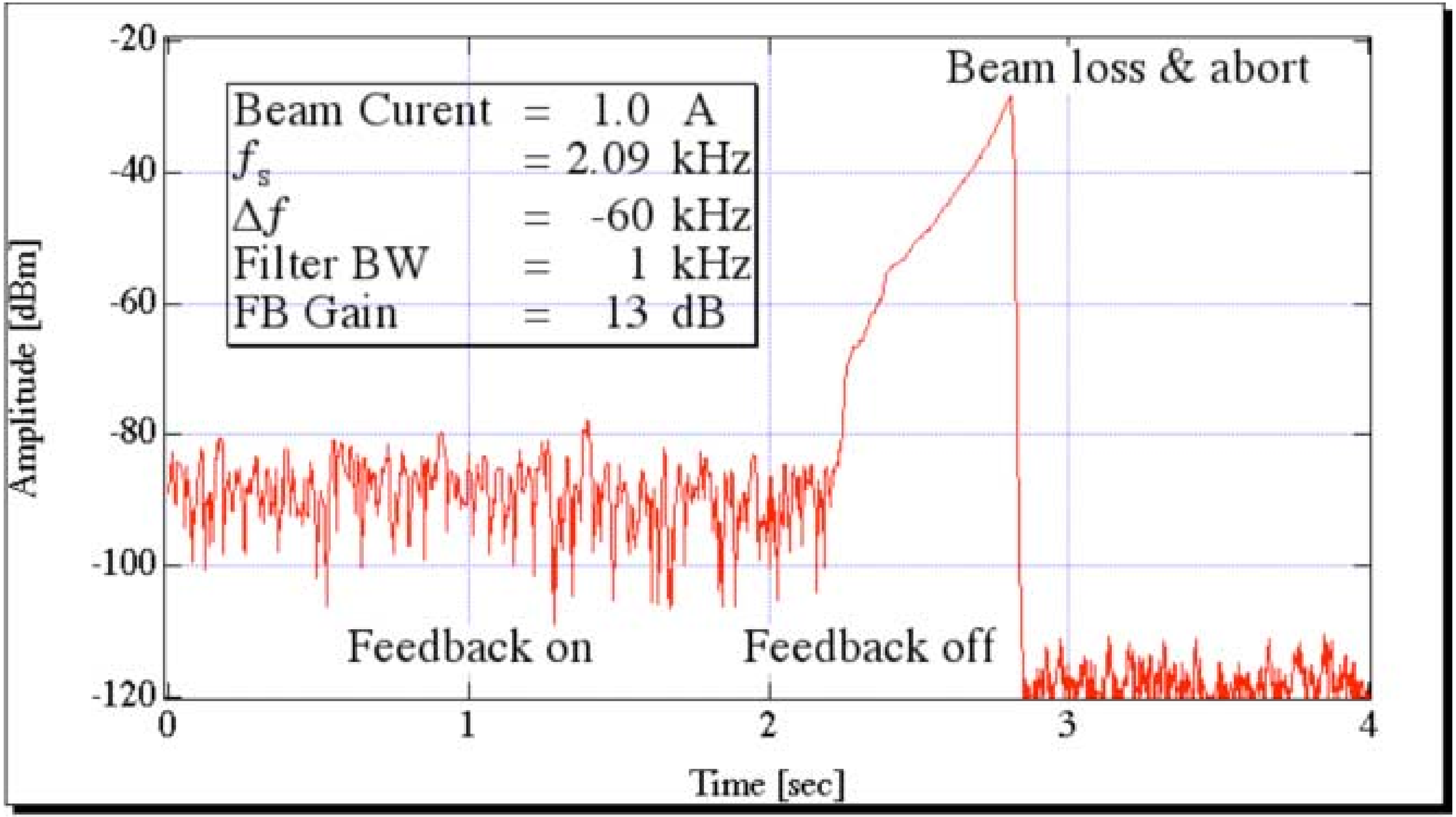
Beam test results in LER (cont'd)

-1 mode spectrum with/without feedback



Beam test results in LER (cont'd)

Time domain behavior with/without Feedback



Summary

- At KEKB, the coupled-bunch instability due to the accelerating mode of the cavity has been suppressed by the high stored energy scheme (ARES and SCC). However, with the increase of beam current, we need a longitudinal feedback system to damp this type of instabilities in LER.
- The -1 mode damper has been tested using the beam of the KEKB LER, and has proved to be effective in damping the coupled-bunch instability of the -1 mode. This system has been incorporated into the RF system and stably operated.
- At Super KEKB, we will need to suppress not only the -1 mode but also the -2, -3 mode.