Instabilities

8th March 1999 KEKB-MAC

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presented by H. Fukuma

1. Introduction

2. Single bunch instability

    1) Summary of design report
    2) Observation

3. Multibunch instability

    1) Summary of design report
    2) Prediction in present operation condition
    3) Observation
    4) Future plan for the study of TMBI

4. Summary

1. Introduction

General situation concerning the instabilities in KEKB

Transverse multi-bunch instabilities(TMBI) are observed in LER and HER.

Owing to the bunch feedback system, beam current reaches to the current of 200 mA and 240 mA in LER and HER respectively.

As for the beam study there are no dedicated and systematic studies for TMBI because the feedback well works to increase the beam current.

Parasitic observation of the instabilities has less reliability because it is affected by various machine conditions such as,

filling pattern,
vacuum pressure,
bunch feedback system,
orbit drift,
chromaticity(head-tail, amplitude dependent tune shift),
tunes,

which are frequently changed to improve the performance of the machines.

Therefore my talk may contain wrong information which will be corrected by future studies.

2. Single bunch instability

2.1 Summary of design report

Bunch lengthening

- No microwave instability is predicted at the design bunch current both in LER and HER.

- Bunch lengthening by the potential well distortion

  LER : 10% increase at design bunch current (0.52mA)
  HER : smaller increase than in LER

2.2 Bunch length measurement by a streak camera

LER : No data
HER : 10% increase at design current (0.22mA)

Re-calculation based on present impedance sources which are not same as those at design stage should be done.

3. Multi-bunch instability

3.1 LER

3.1.1 Summary of design report

- Growth time of the instability (τ_g)

Energy : 3.5 GeV, beam current : 2.6 A
(Radiation damping time τ_{rad} x/y/z : 74/84/45 ms)

Cavity HOM	30 ms (long.)
	20 ms (trans.)
Resistive wall	6 ms
Photoelectron instability(PEI)	0.15 ms

3.1.2 Predicted τ_g in present operation condition

Beam current : 200mA

Cavity HOM	> τ_{rad}
Resistive wall	80 ms
PEI	1 - 2 ms (@150mA)

3.1.3 Observation

1) Example of a beam fill

Condition :Bunch spacing;10 buckets, 460 bunches,
feedback on

Injection efficiency became worse as beam current increased.
The beam current almost saturated at 150 mA.

More bunches (bunch spacing 5 buckets) were added.
The beam current almost saturated at 190 mA.

More bunches (bunch spacing 2 buckets) were added.
The beam current saturated at 200 mA.
Beam loss occurred in some bunches.

Beam current seem to be limited by TMBI.

Damping time of the feedback system is estimated to be 1 - 2ms if well tuned.

-> Growth rate of the instability : 1 - 2 ms ?

(caution : we do not know the damping time of the feedback system at this observation.)

2) Bunch spacing vs. max. current

Condition : Almost uniform fill (bunch gap of 512 buckets for beam abort), feedback off

When the bunch spacing is less than 10 buckets maximum storable current is very small.

-> Range of the wake is about 10 buckets.

3) Without feedback the beam spectrum has vertical sideband. The vertical instability is stronger than the horizontal one.

3.1.4 Discussion

Growth rate of the instability is same order of magnitude as that of PEI ?.

Measurement of bunch spacing vs. max. current is consistent with PEI ?.

The possibility that HOMs in "cavity" structures cause the instability is not excluded. We do not measure the beam spectrum in whole frequency range.

3.2 HER

3.2.1 Summary of design report

Growth time of the instability (τ_g)

Energy : 8 GeV, beam current : 1.1 A
(Radiation damping time τ_{rad} x/y/z : 45/46/23 ms)

Cavity HOM	longer than in LER
Resistive wall	4 ms
Fast ion instability(FII)	1 ms

3.1.2 Predicted τ_g in present operation condition

Beam current : 240mA

Cavity HOM	$> \tau_g$
Resistive wall	18 ms
FII	$\approx$ 1 ms

3.2.3 Observation

1) Example of a beam fill

Initial condition : # of train 8, 60 bunches/train, bunch spacing 5 buckets, feedback on

The beam current saturated at 210 mA.

Beam loss occurred at the tail part of the trains.

In beam spectrum horizontal and vertical sideband appeared.

Beam current seem to be limited by TMBI.

Damping time of feedback system is estimated to be 1 - 2ms if well tuned.

-> Growth rate of the instability : 1 - 2 ms ?

(caution : we do not know the damping time of the feedback system at this observation.)

2) Data from feedback study

Output of the two tap filter shows that horizontal amplitude seem to grow along the bunch train.

Bunch spectrum shows that the horizontal instability is stronger than that of the vertical one.

3) Fill pattern vs. max. current

Condition : feedback off

•Almost uniform fill (bunch gap of 512 buckets for beam abort), bunch spacing 40 bucket

-> max. current 79 mA

•8 bunch train, 10 bunch spacing, 40 bunch/train

-> max. current 114 mA

4) Intensity profile of trains after a beam fill w/o feedback

Head > Tail

3.2.4 Discussion

Fill pattern measurement implies that the instability is ion related.

Intensity profile after a beam fill implies larger oscillation amplitude of tail part than that of head in a train.

Growth rate of the instability is same order of magnitude as FII ?.

FII simulation can not explain that horizontal instability is stronger than vertical one.

3.3 Future plan for the study of TMBI

Single pass BPM system(SBPM) with memory boards, which is under preparation by the feed back group, is to be available soon. SBPM is essential to measure the oscillation pattern of the bunches.

(Taking a beam spectrum by a spectrum analyzer is very time consuming due to large harmonic number of 5120 and seems to be practically impossible.)

SBPM allows to study

oscillation mode,
growth rate,
amplitude saturation and so on

as a function of

fill pattern,
bunch current,
beam size,
vacuum pressure etc.

Dedicate machine time is also essential for further study.

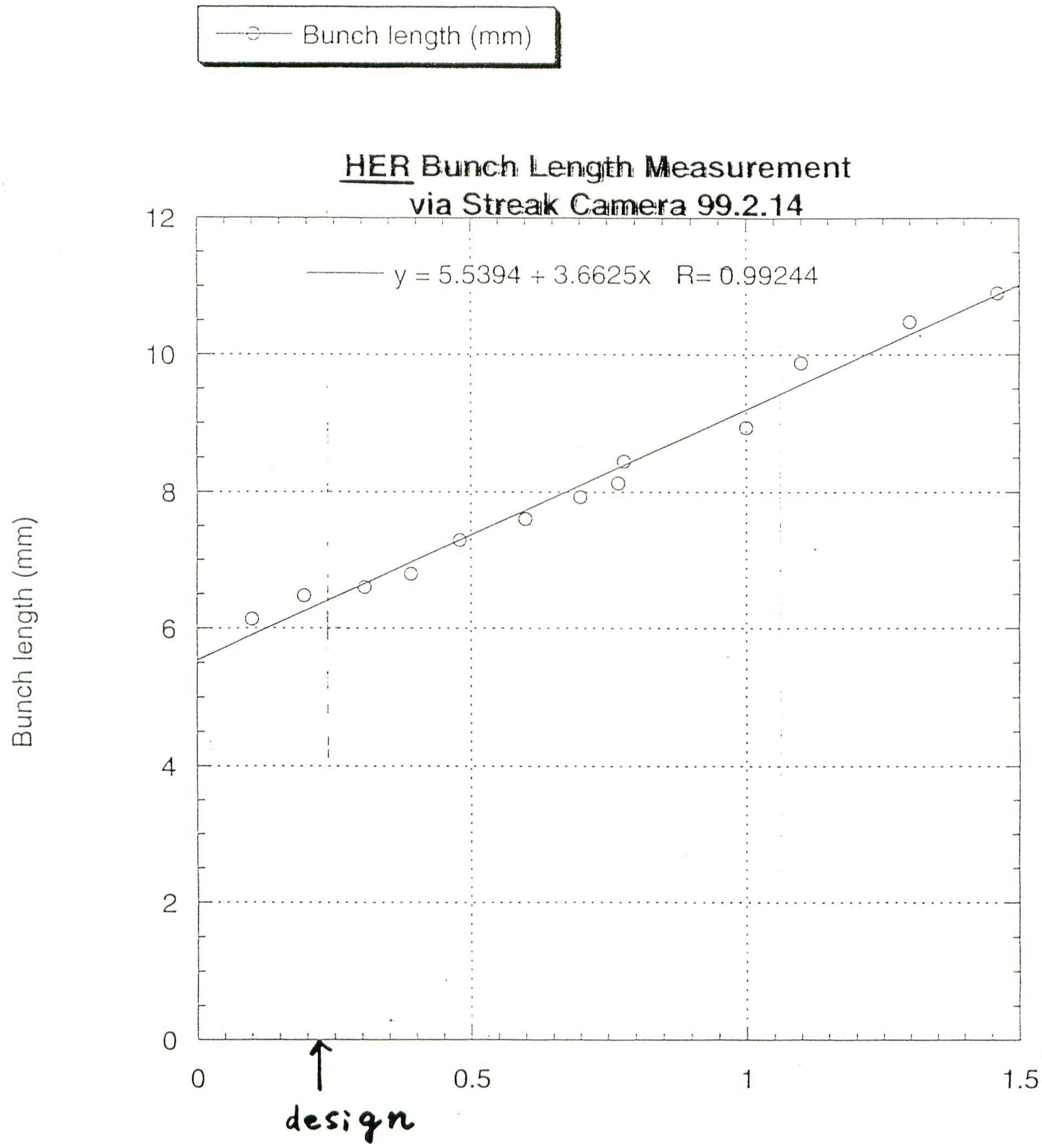
4. Summary

Transverse coupled bunch instabilities are observed in LER and HER.

The instabilities are suppressed by the bunch feedback system.

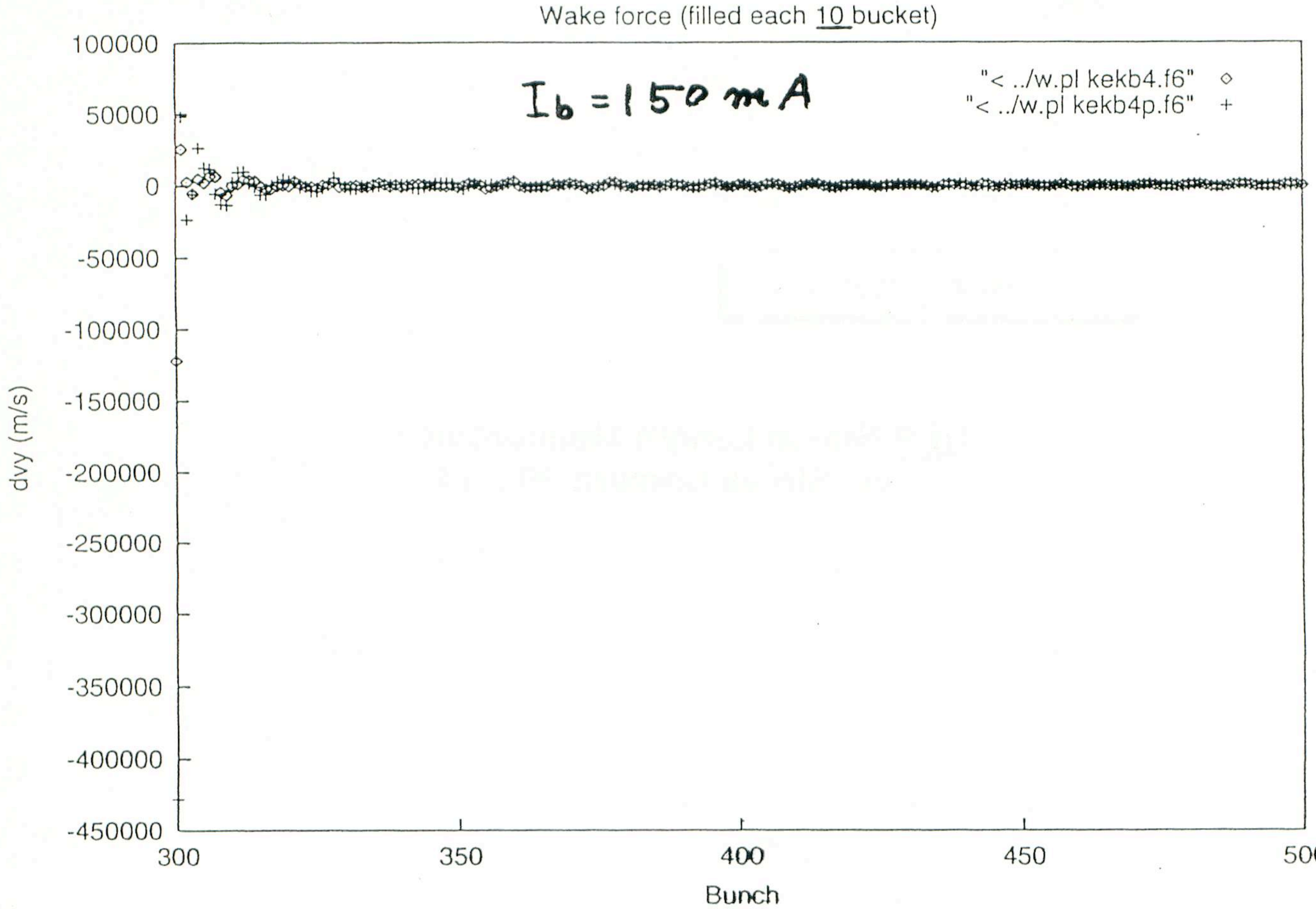
Source of the instabilities is not identified yet.

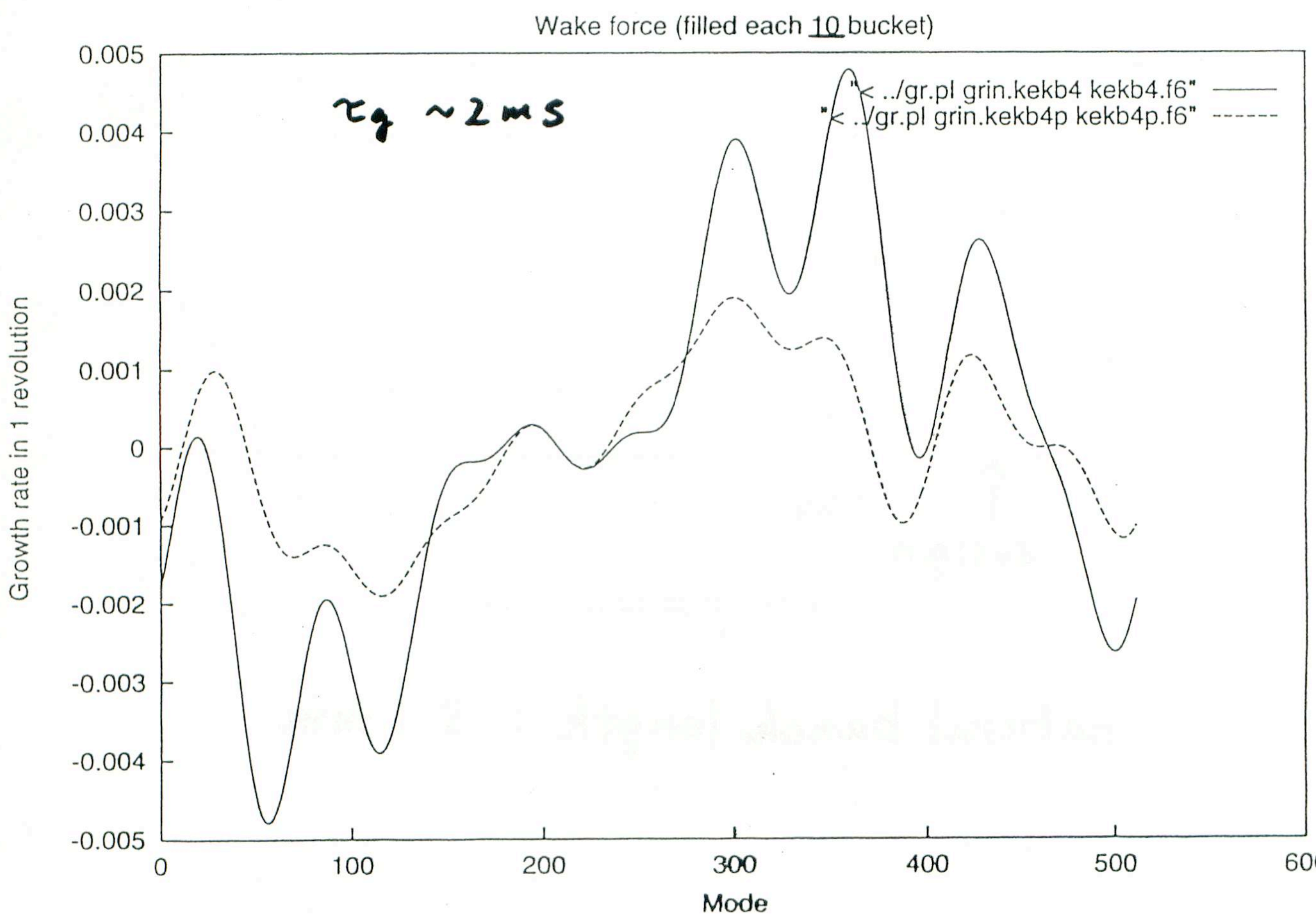
To study the instabilities further, dedicated machine time and SBPM system is essential.

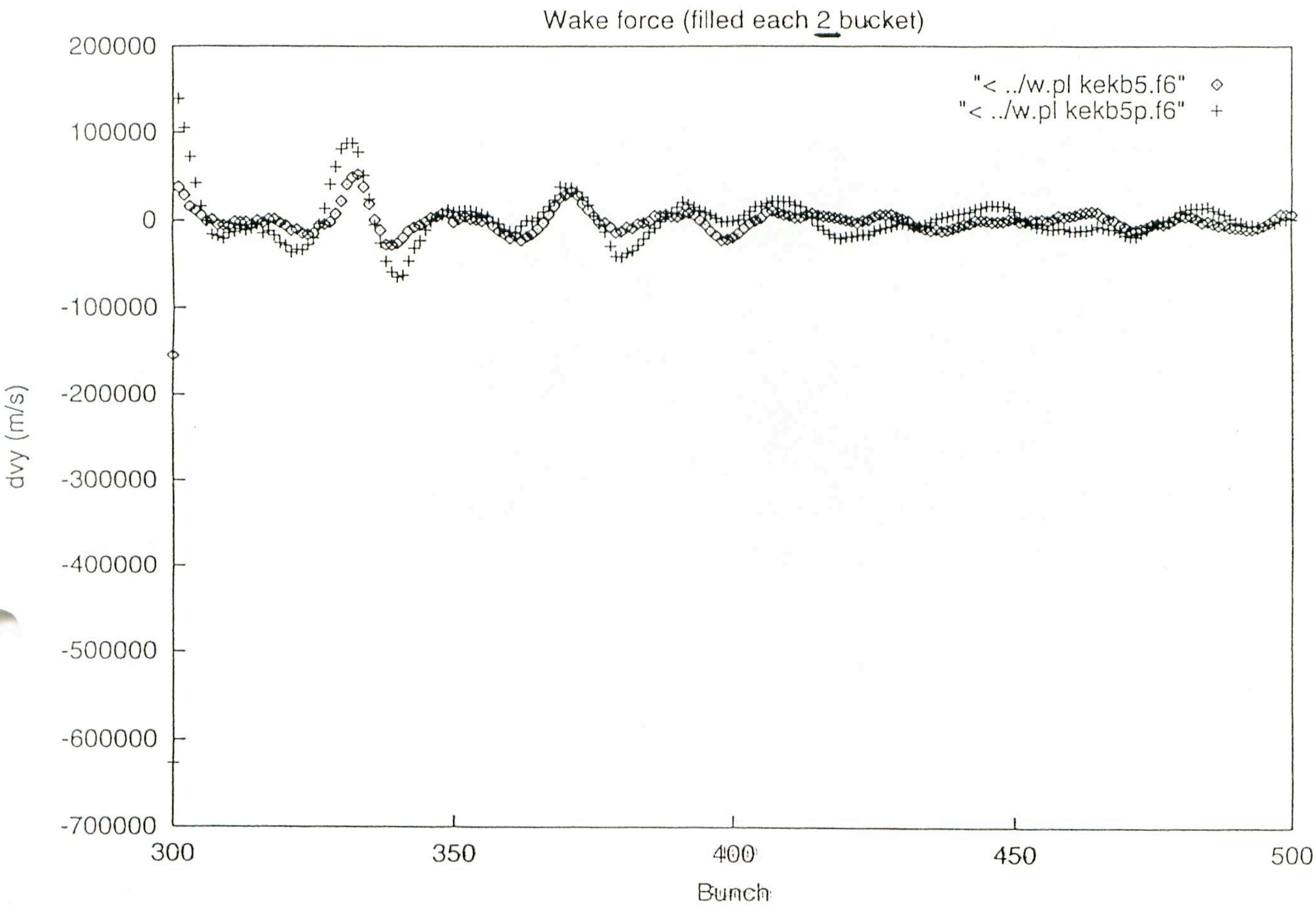


natural bunch length : 5.1 mm

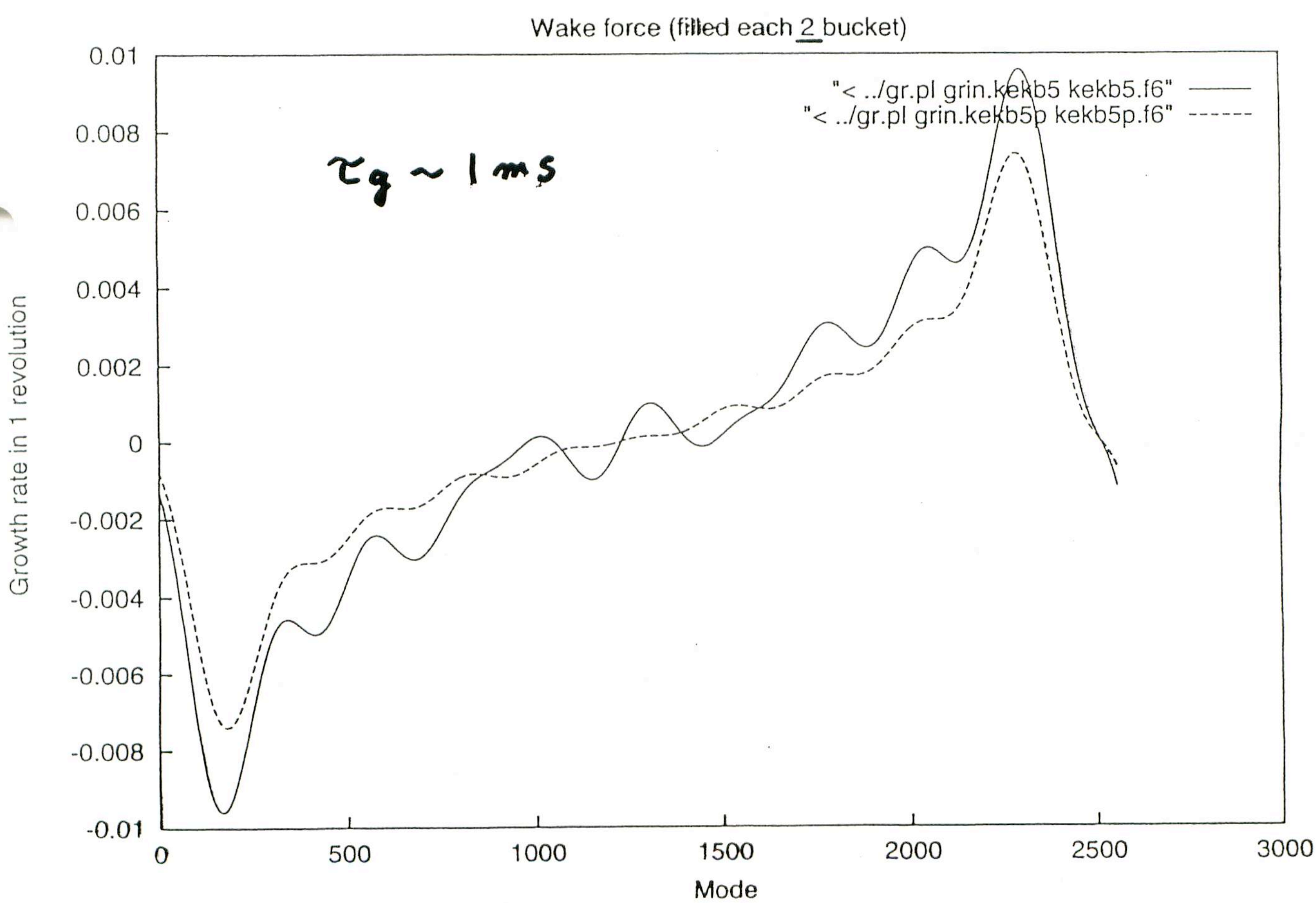
PEI simulation K. Ohmi



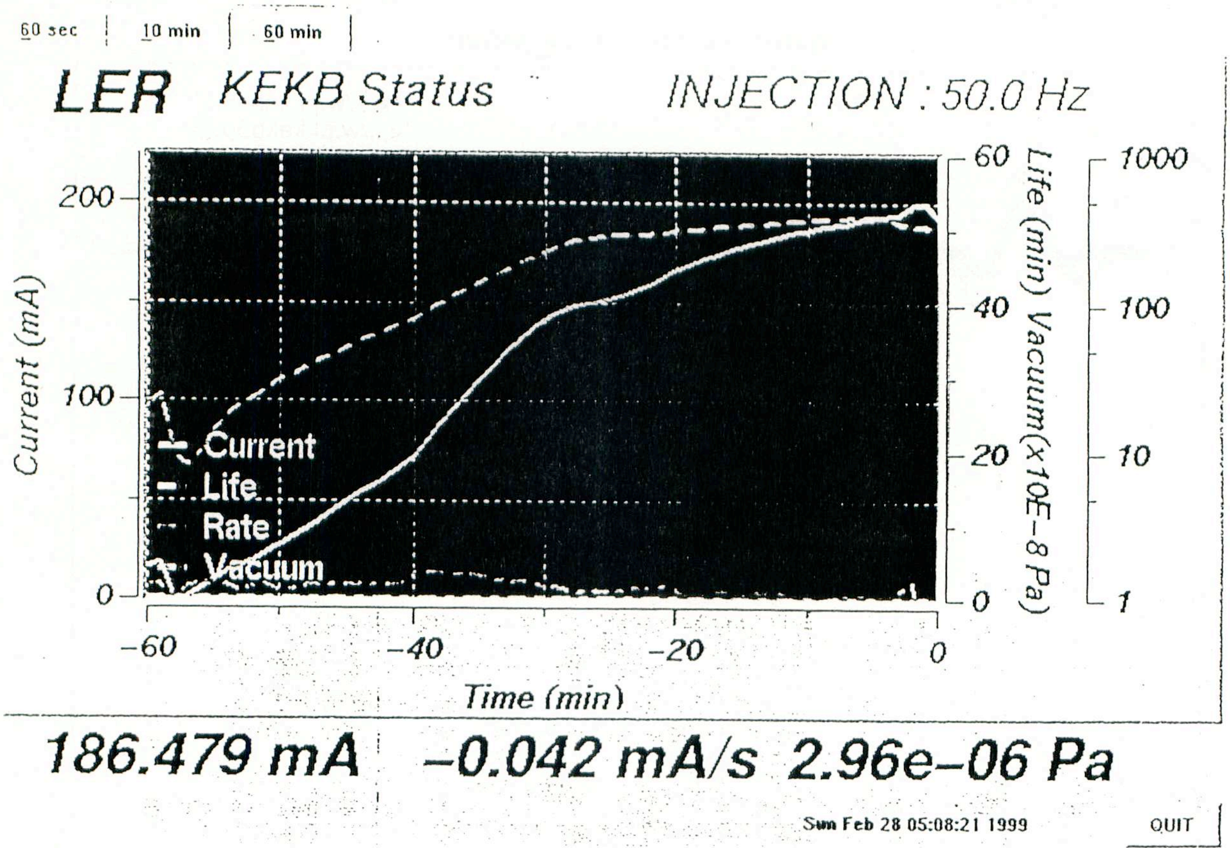


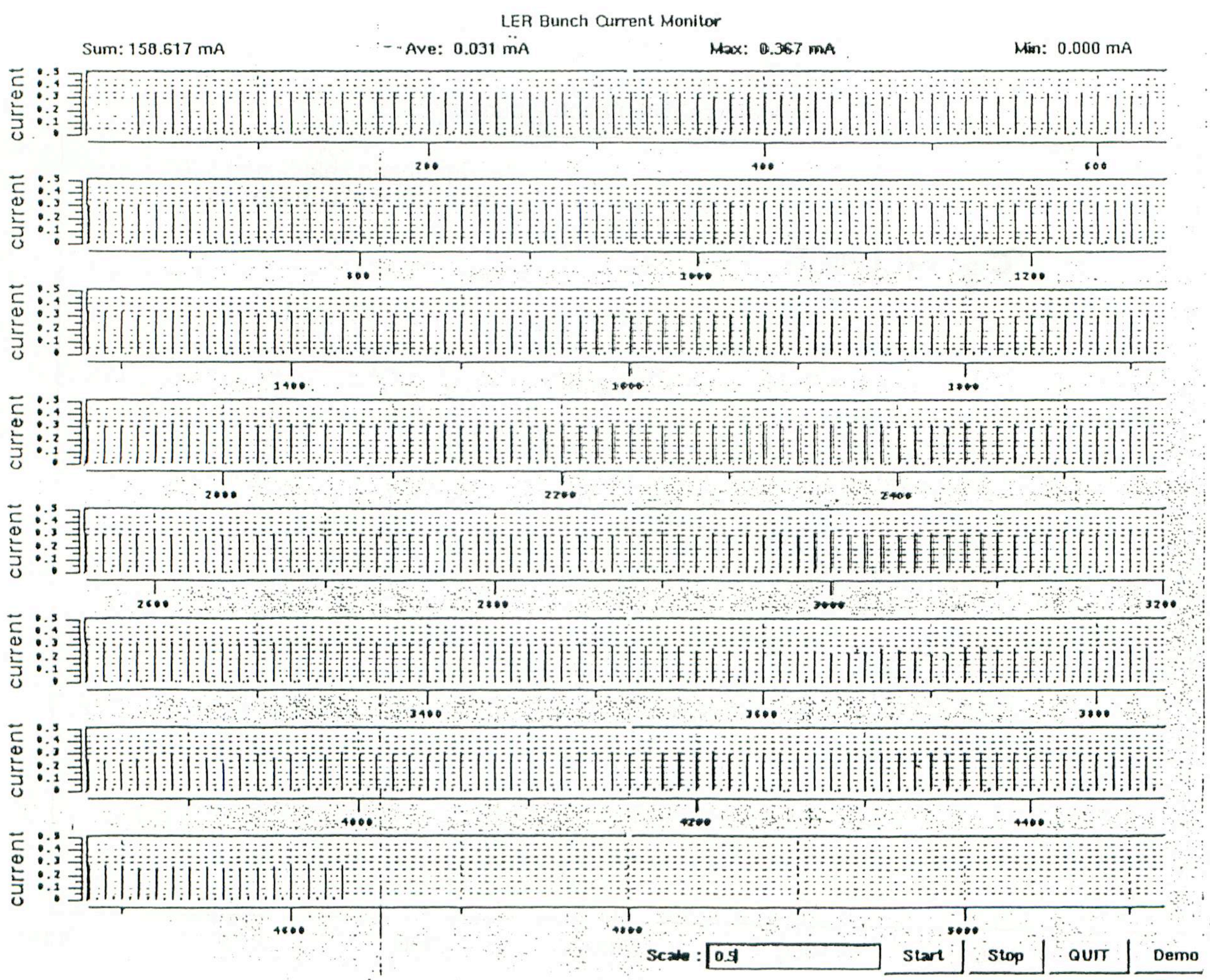


Wake force (filled each 2 bucket)
"< ../w.pl kekb5.f6"
"< ../w.pl kekb5p.f6"
dvy (m/s)
200000
100000
0
-100000
-200000
-300000
-400000
-500000
-600000
-700000
300
350
400
450
500
Bunch

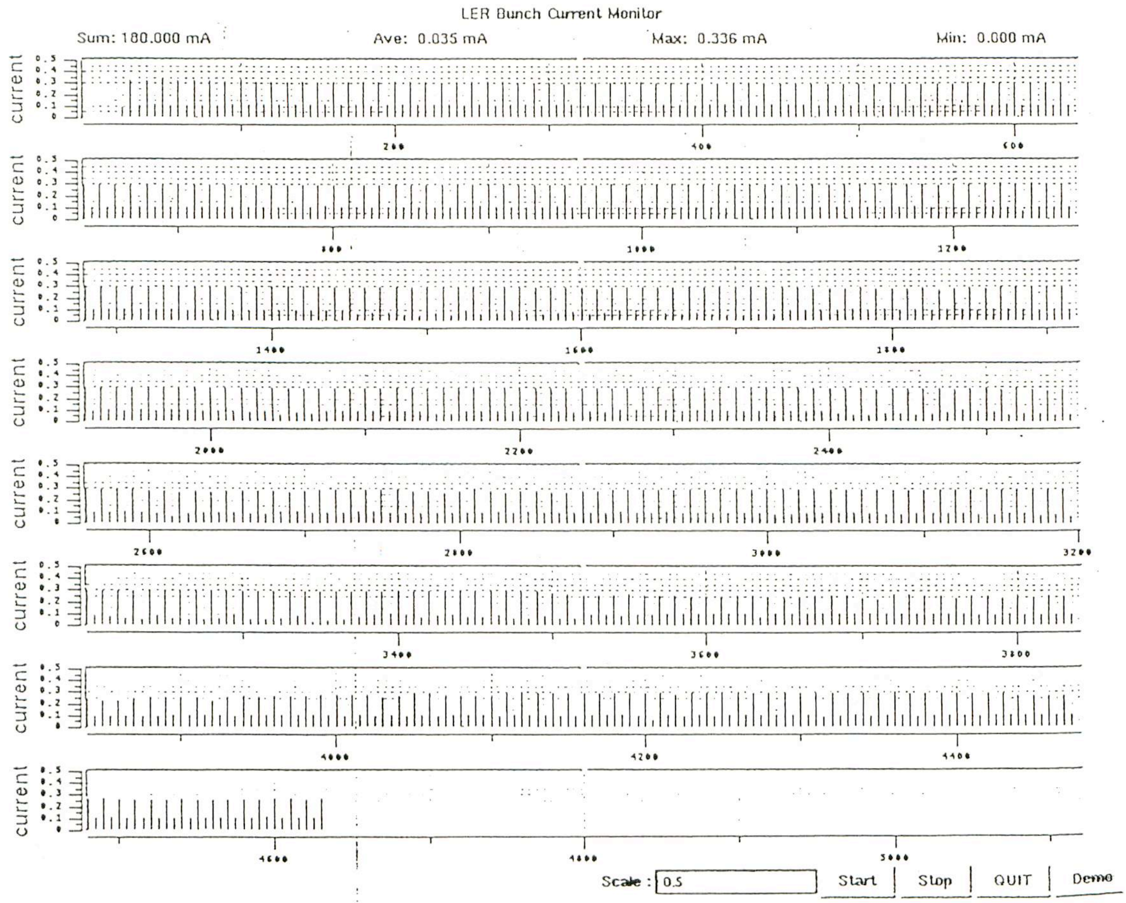


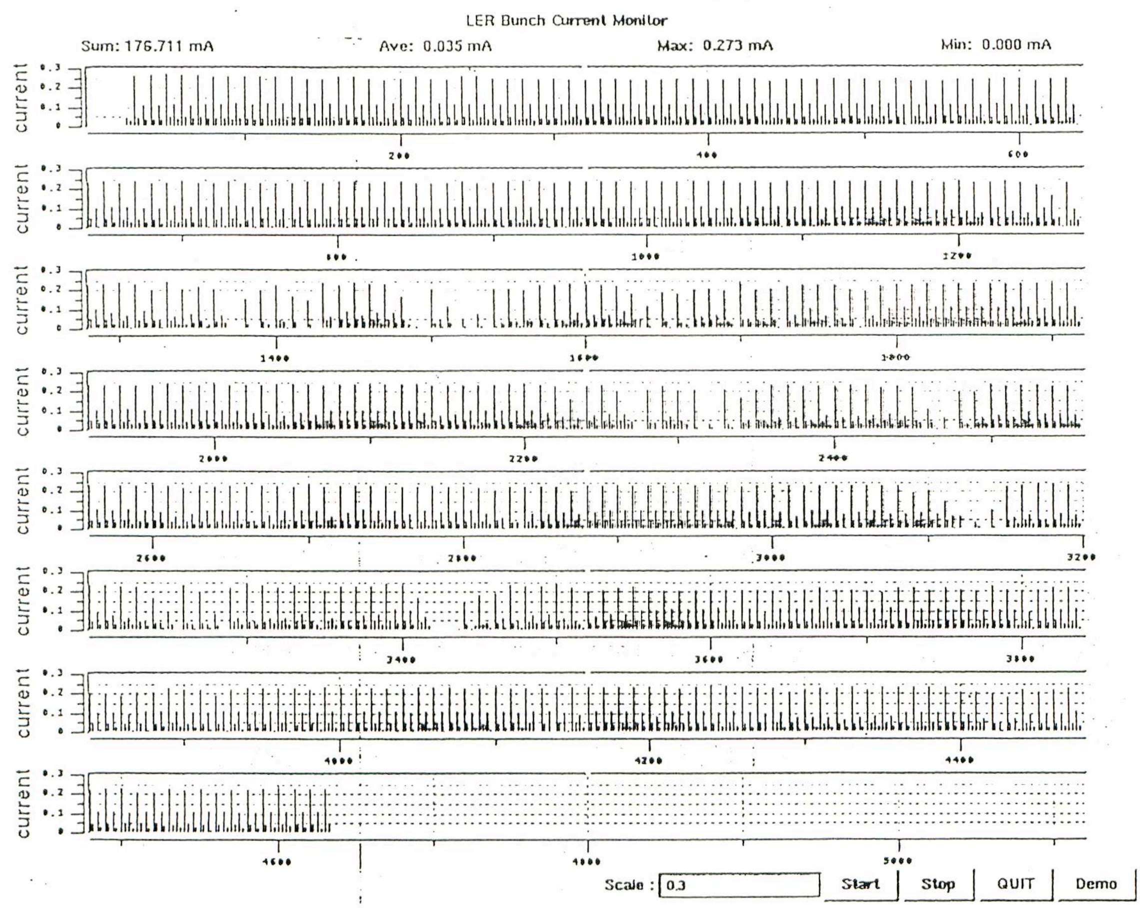
Wake force (filled each 2 bucket)
"< ../gr.pl grin.kekb5 kekb5.f6"
"< ../gr.pl grin.kekb5p kekb5p.f6"
τg ~ 1 ms
Growth rate in 1 revolution
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
0
500
1000
1500
2000
2500
3000
Mode


60 sec
10 min
60 min
LER KEKB Status
INJECTION : 50.0 Hz
Current (mA)
Life (min) Vacuum(x10E-8 Pa)
Current
Life
Rate
Vacuum
Time (min)
186.479 mA
-0.042 mA/s
2.96e-06 Pa
Sun Feb 28 05:08:21 1999
QUIT

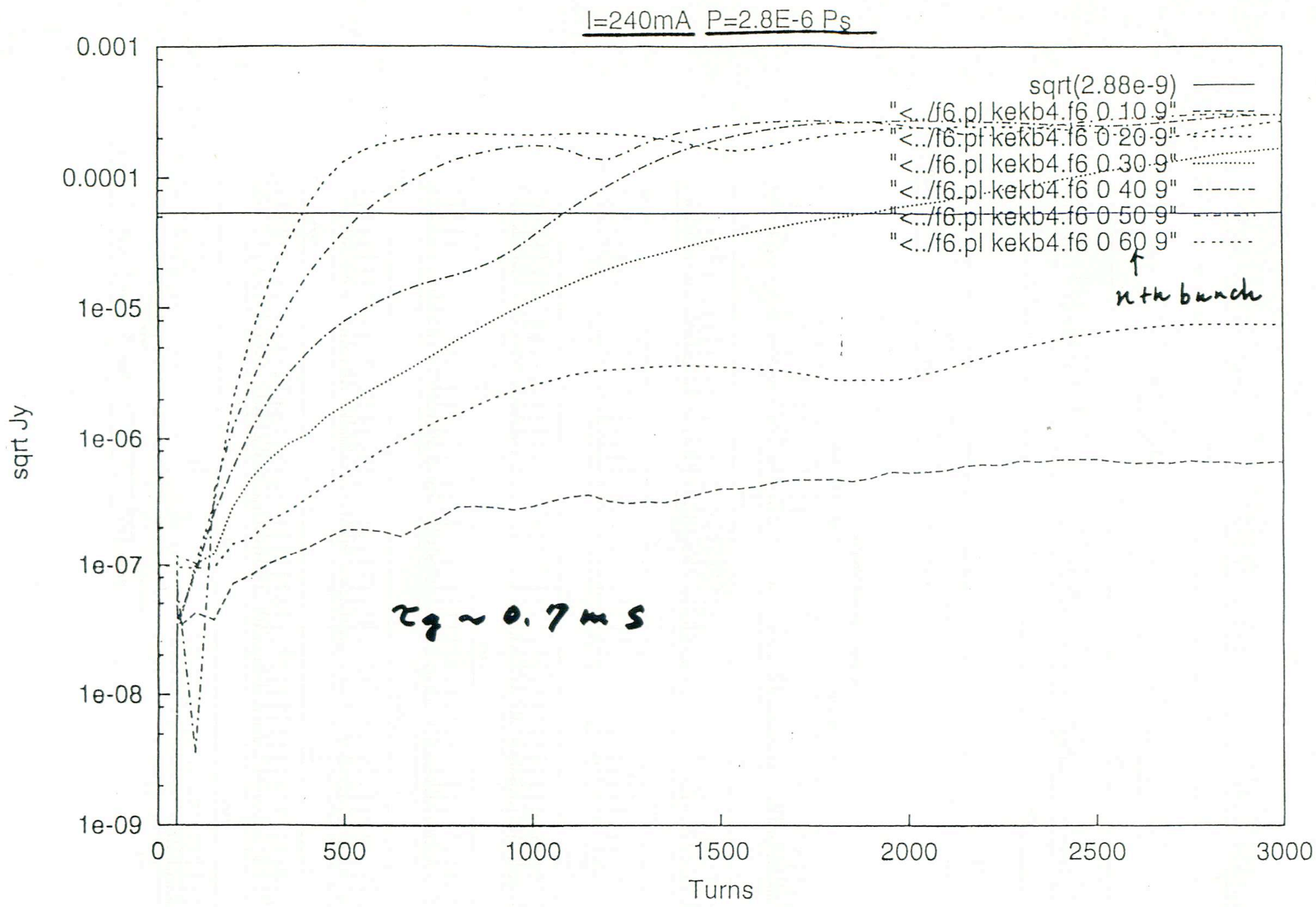

LER Bunch Current Monitor
Sum: 158.617 mA
Ave: 0.031 mA
Max: 0.367 mA
Min: 0.000 mA
current
Scale : 0.5
Start
Stop
QUIT
Demo

LER


LER Bunch Current Monitor
Sum: 180.000 mA
Ave: 0.035 mA
Max: 0.336 mA
Min: 0.000 mA
current
Scale : 0.5
Start
Stop
QUIT
Demo


LER Bunch Current Monitor
Sum: 176.711 mA
Ave: 0.035 mA
Max: 0.273 mA
Min: 0.000 mA
current
Scale : 0.3
Start
Stop
QUIT
Demo

FII simulation

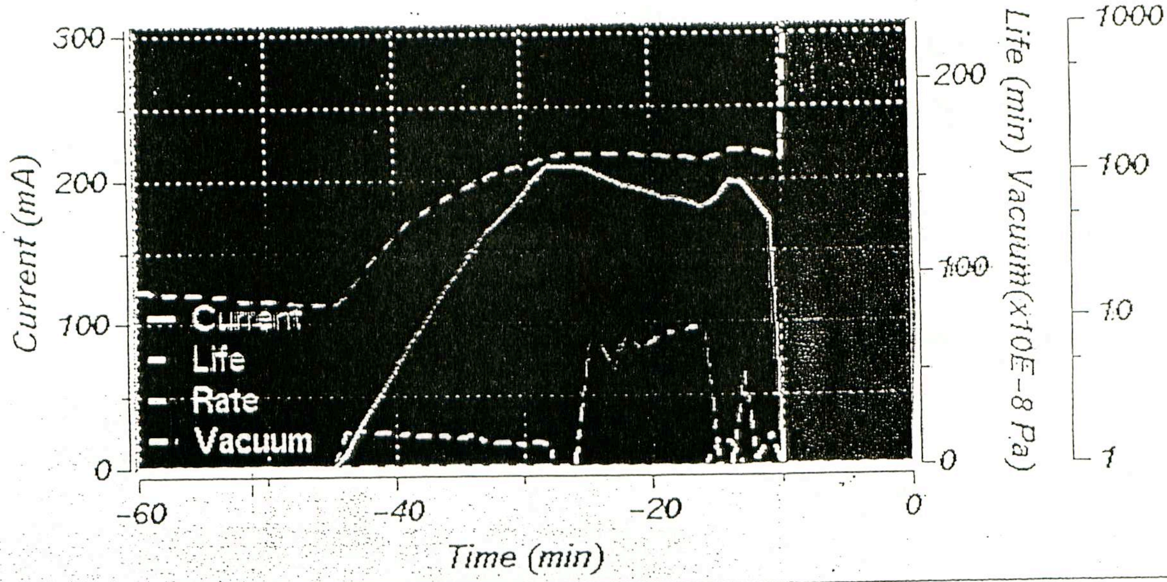


- Train 8
- Bunch spacing 5 bucket
- 60 bunch/train

$\sigma_y = 200\,\mu m$

60 sec | 10 min | 60 min

HER KEKB Status



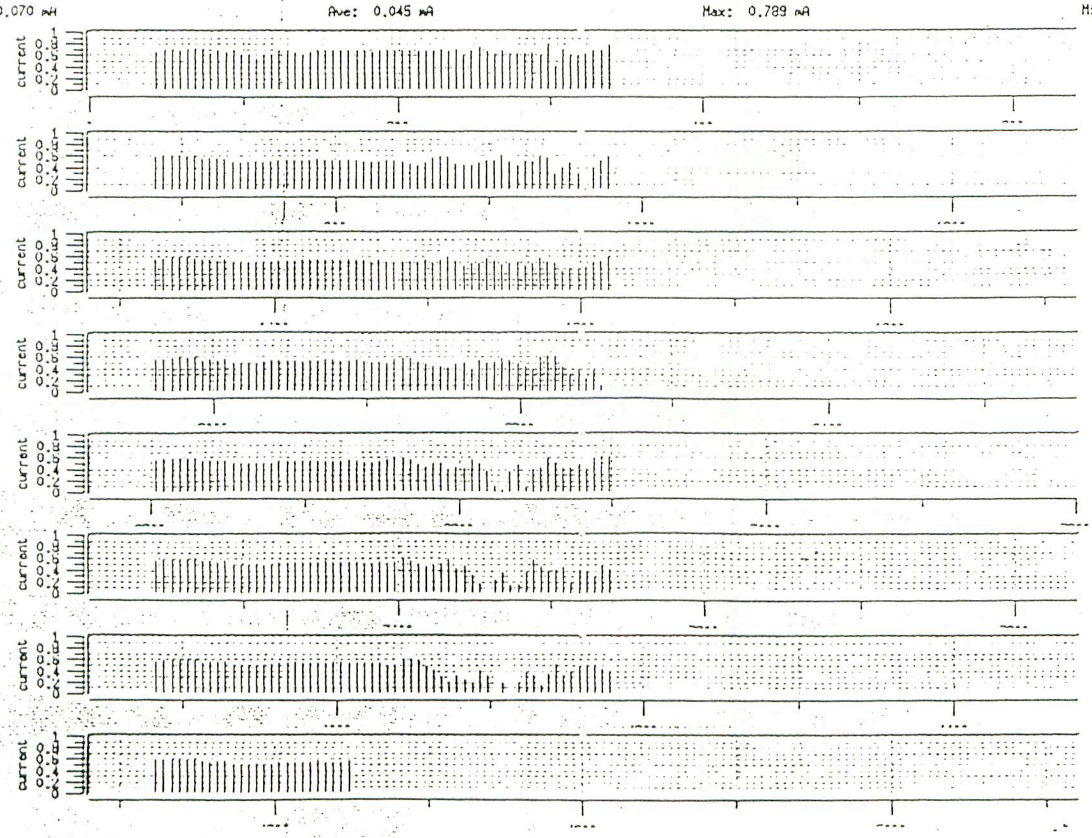
−0.013 mA   0.0 min   0.000747 Pa

Sun Feb 28 06:56:32 1999

QUIT

HER Bunch Current Monitor

Sum: 230.070 mA   Ave: 0.045 mA   Max: 0.789 mA   Min: 0.000 mA



Scale : 1.0   Start   Stop   QUIT   De

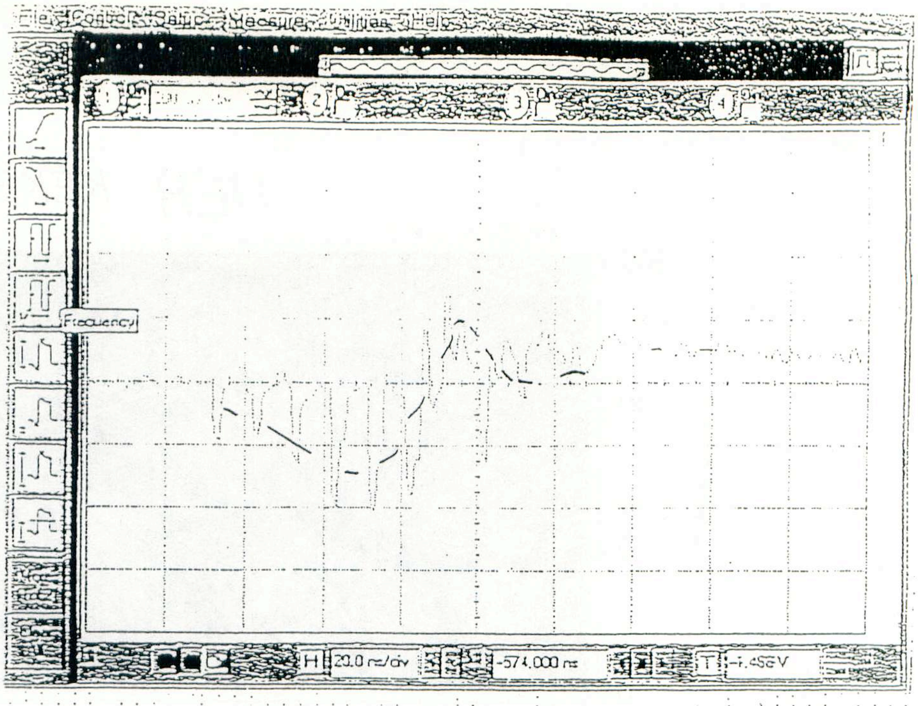
HER

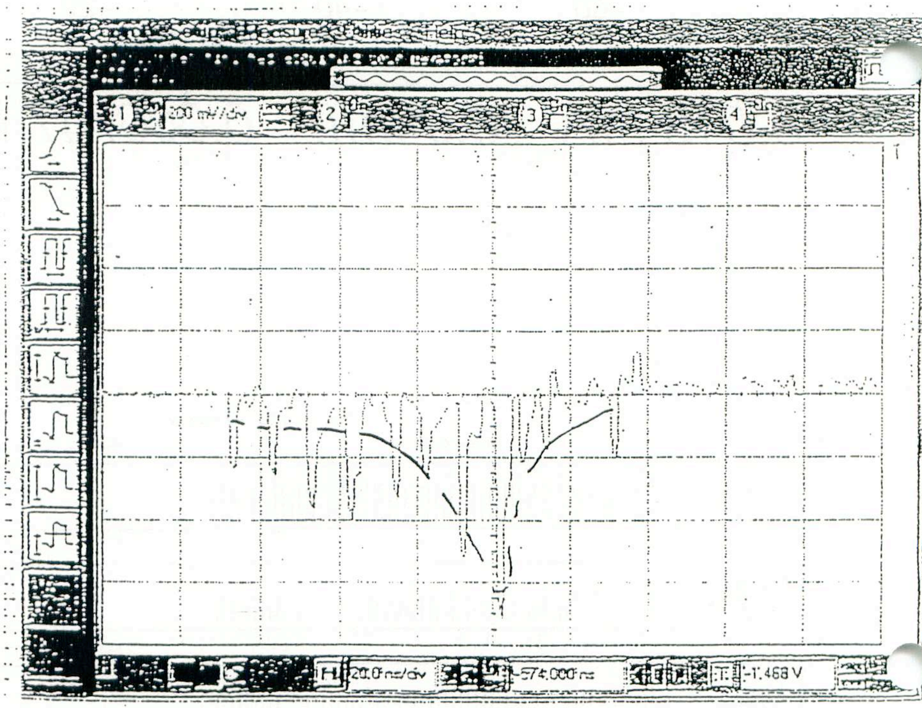
Output of two tap filter

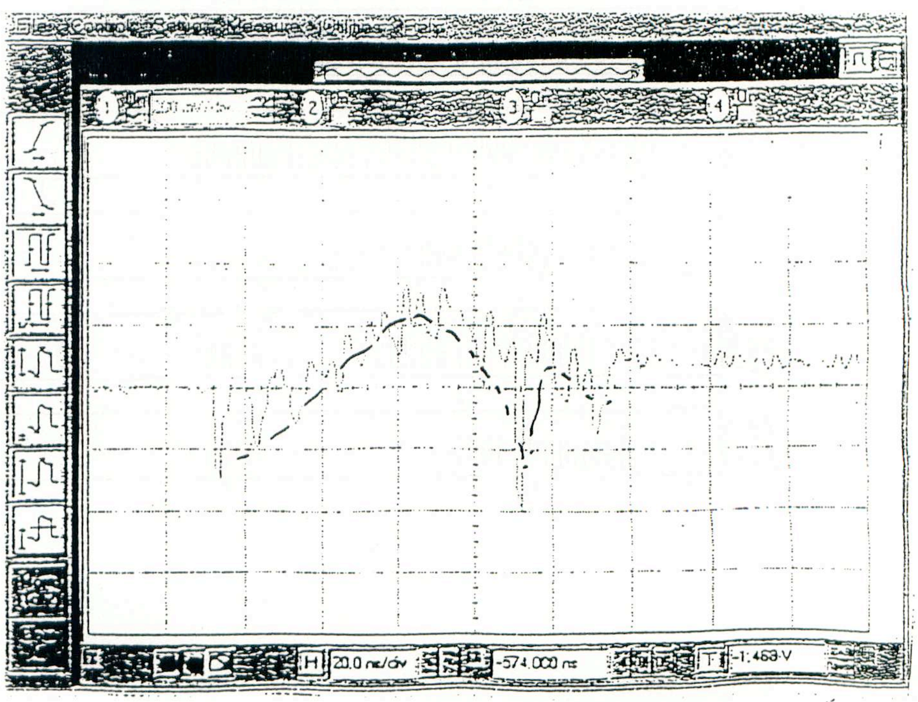
I = 64 mA

Horizontal

Feedback OFF

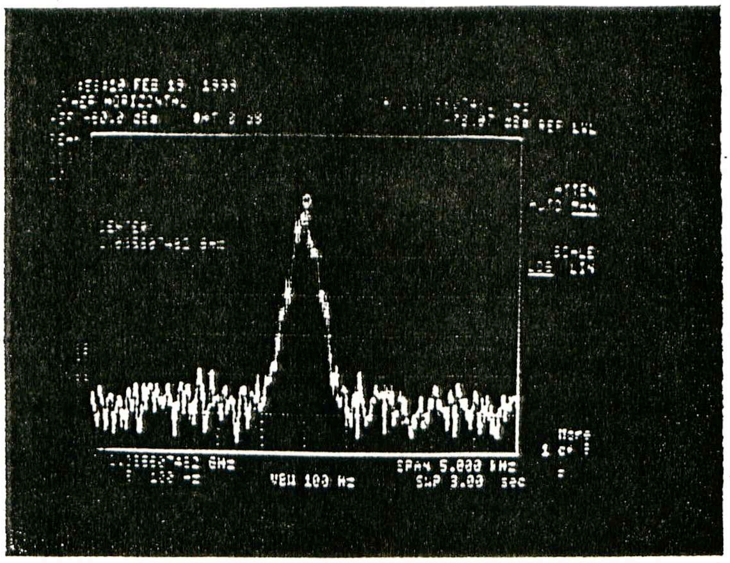




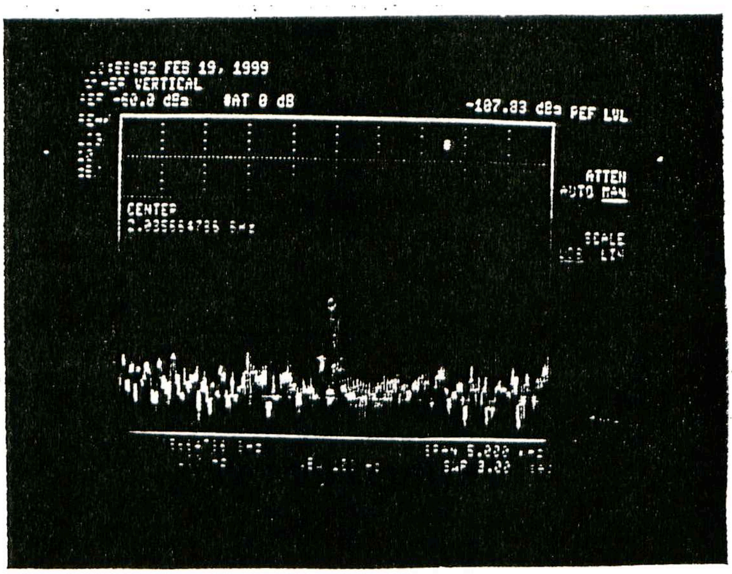


HER (Feedback OFF)

Train 8, bunch spacing 5 bucket, 20 bunch per train

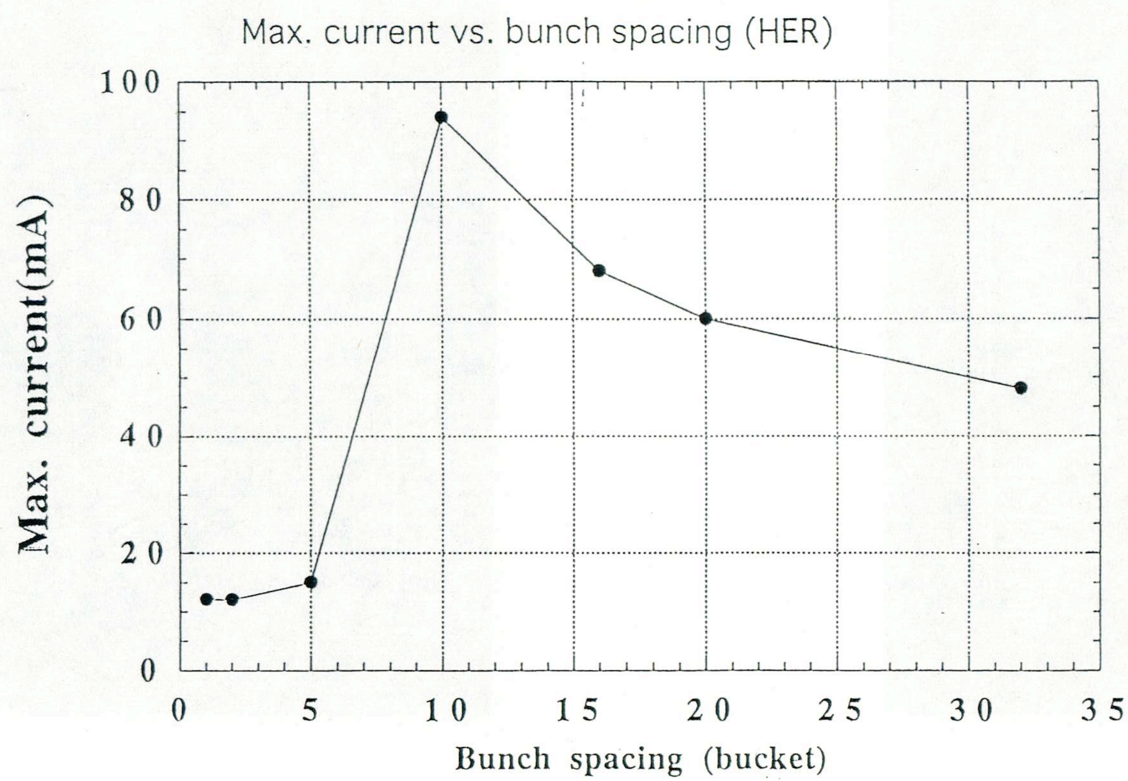


H



V

Beam spectrum


Max. current vs. bunch spacing (HER)
Max. current(mA)
100
80
60
40
20
0
0
5
10
15
20
25
30
35
Bunch spacing (bucket)