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Impedance database and application at APS

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Advanced Photon Source, ANL
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Talk Outline

Impedance Database
- Goal/Method
- Examples
- Total Impedance

Application
- Longitudinal: Microwave
- Horizontal: Saw-tooth
- Vertical: TMCI

Discussion

Conclusion

Impedance Database

GOAL: Total Wake Potential

$$W_{total} = \sum_{Element} N_i * W_i * \alpha_i ,$$

W_{total} = total wake-potential of the ring,

N_i = number of the element in the ring,

W_i = wake-potential of the element,

α_i = weight of the element.

Method: Standard Wake Potential

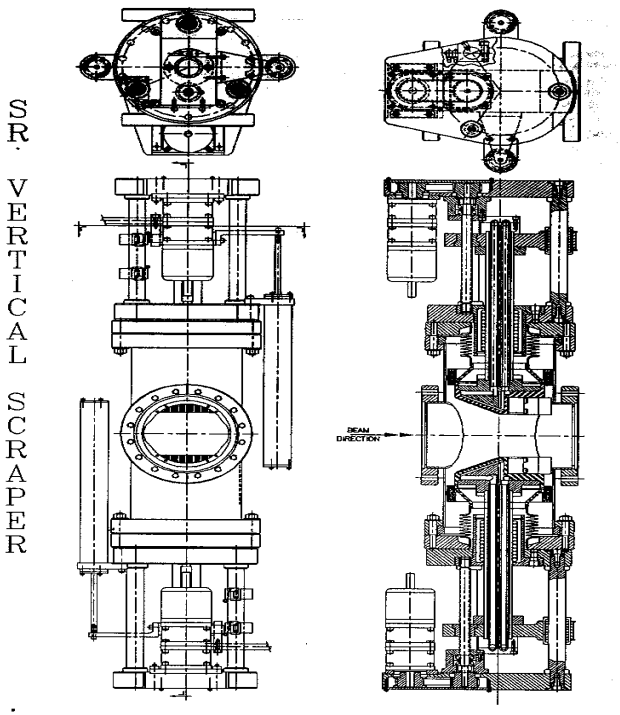
1. Data in SDDS forms: s, Wx, Wy, Wz
2. Uniform Simulation Condition
   - Rms bunch length = 5mm
   - Mesh size smaller than 0.5 mm
   - Wake length larger than 0.3 m
3. Deposit the authorized wake potentials in the designated directory
   ➔ Available to everyone who has access

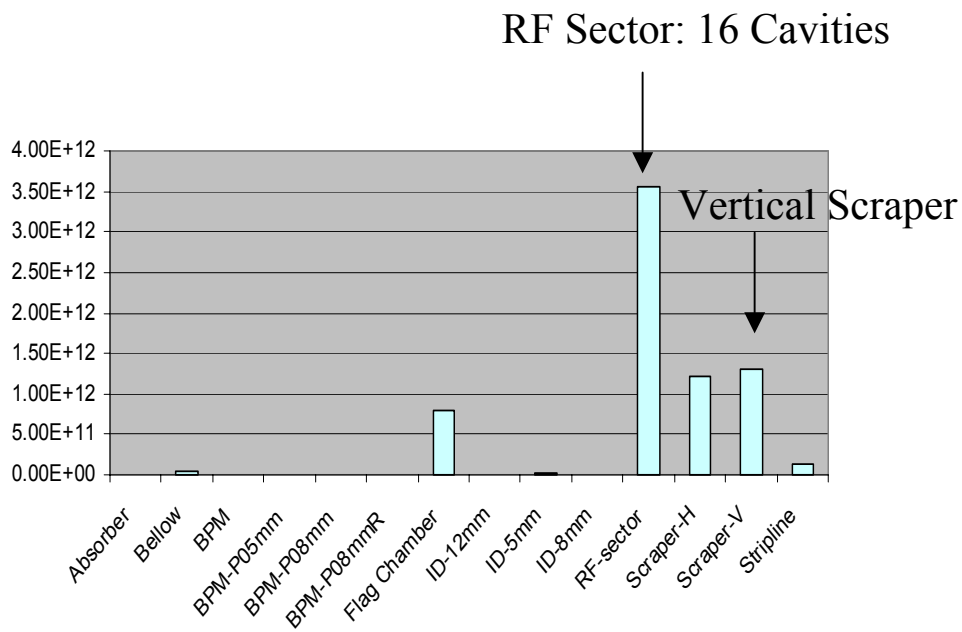
Impedance Database: Example

VERTICAL SCRAPER

VERTICAL SCRAPER IS HOT!!!
THE LOSS FACTOR IS 1.2 V/pC

The current 100 mA in 25 bunch will deposit 20 W into the small cavity area.



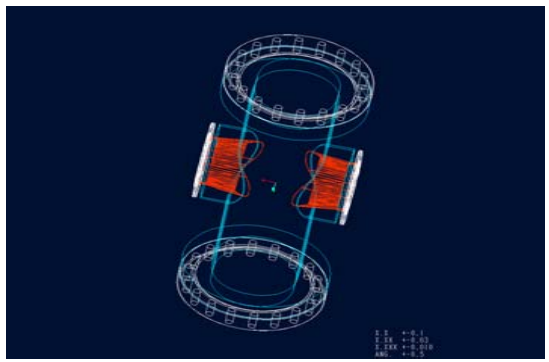


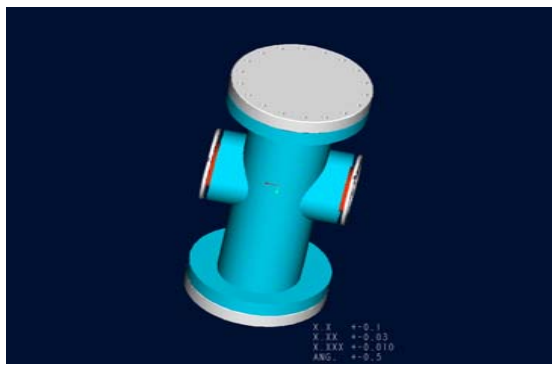
Loss Factor of Each Element

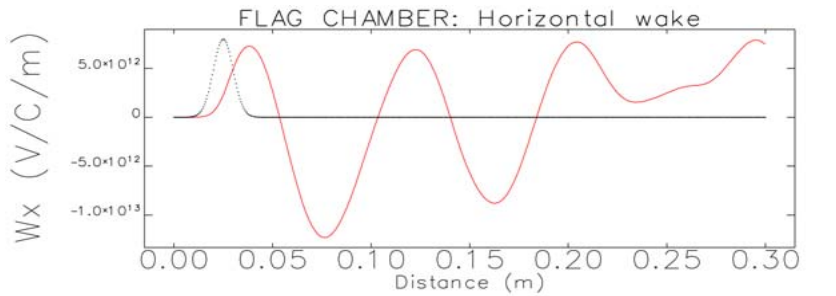
Impedance Database: Example

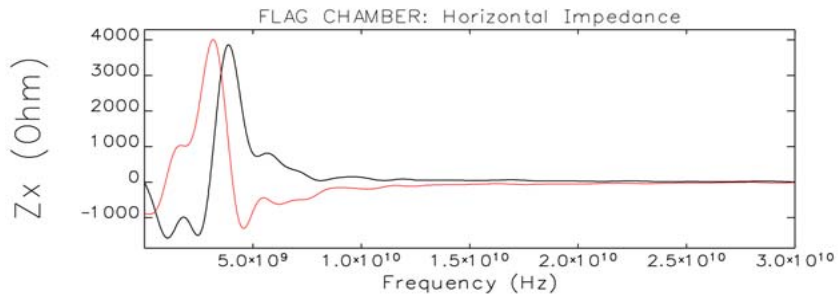
FLAG CHAMBER

FLAG CHAMBER WAS SURPRISE
IN THE APS STORAGE RING.



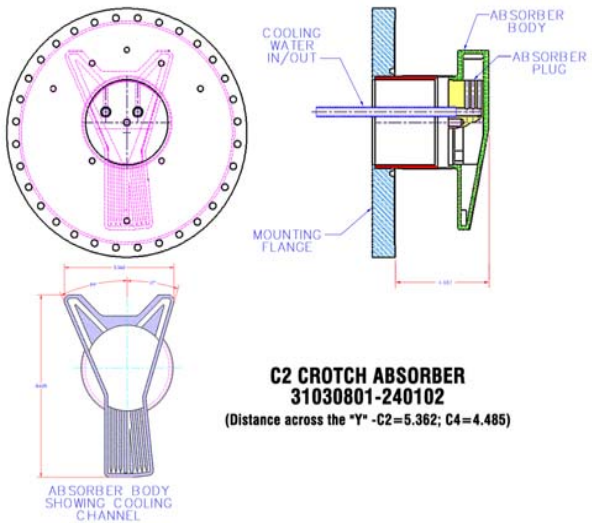


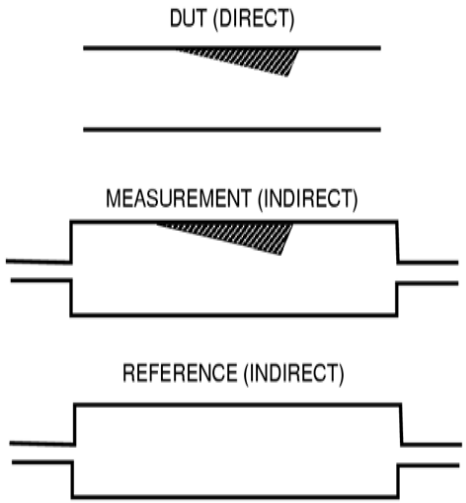


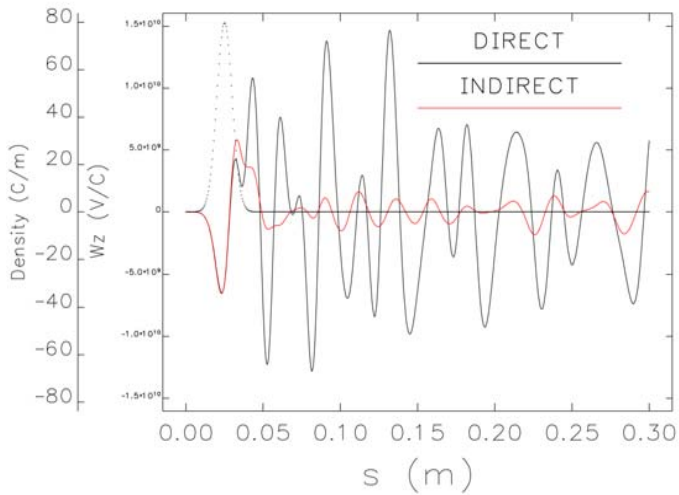


Impedance Database: Example

SYNCHROTRON RADIATION ABSORBER





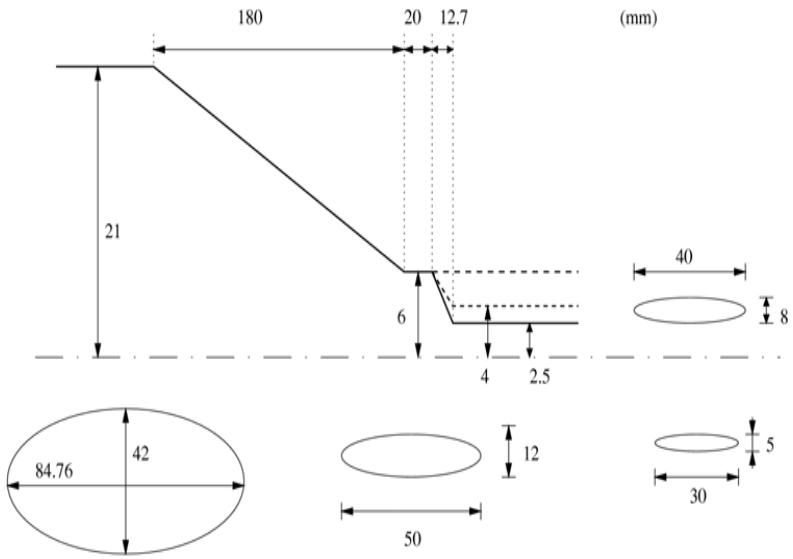


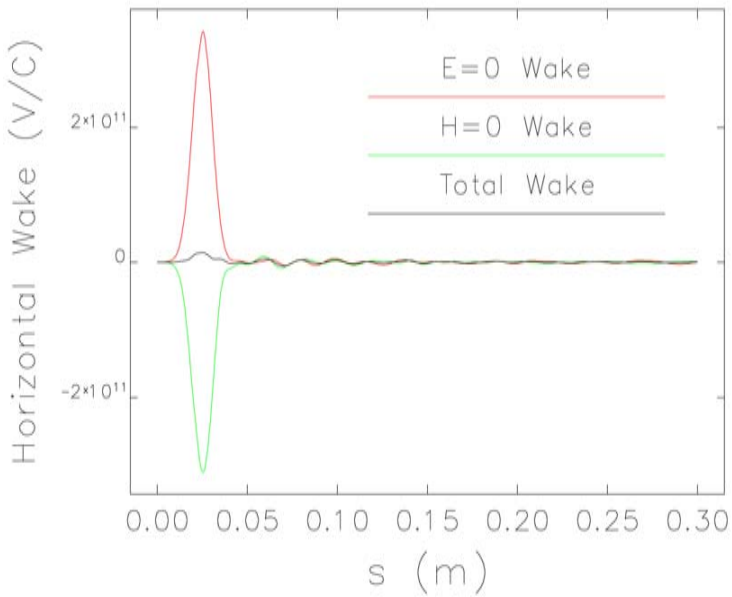
component method result

Impedance Database: Example

INSERTION DEVICE CHAMBER: HORIZONTAL

1. E-Wake is POSITIVE (DEFOCUSING)
2. H-Wake is NEGATIVE (FOCUSING)
3. Cancels Each Other ➔ Negligible!



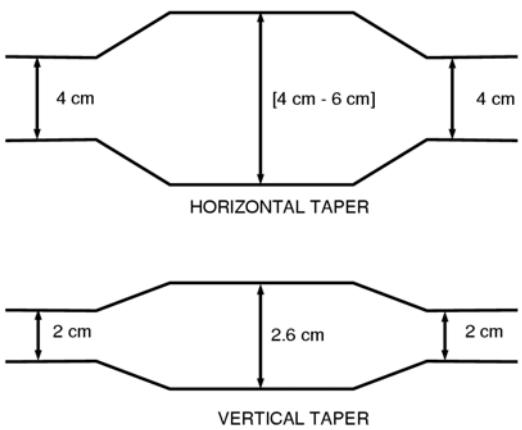


Impedance Database: Example

TRANSVERSE FOCUSING WAKE

CONJECTURE

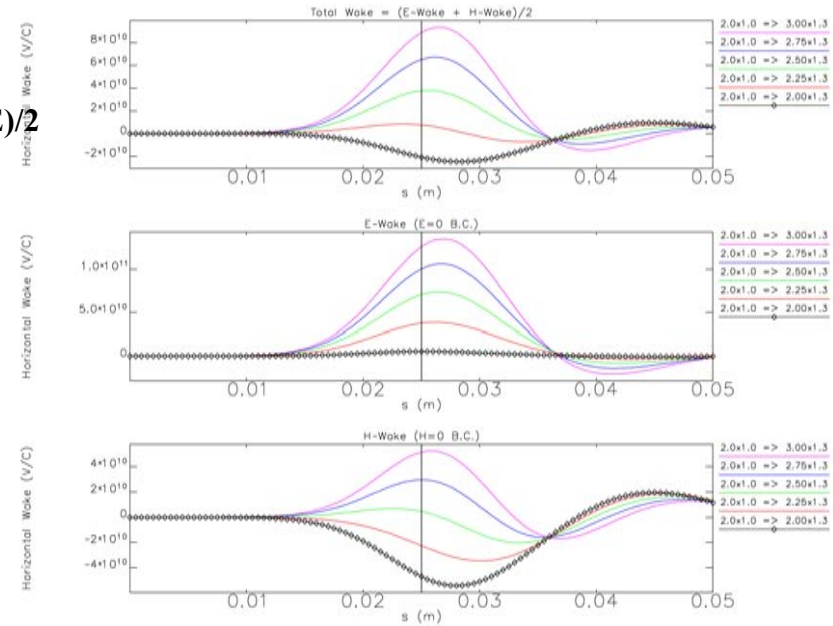
1. **The negative wake potential is a completely 3-D phenomena,**
2. **It can occur when the degree of perturbation in one dimension is greater than in the other,**
3. **The negative wake potential is in the plane of the smaller perturbation.**



TOTAL= (E-WAKE+H-WAKE)/2

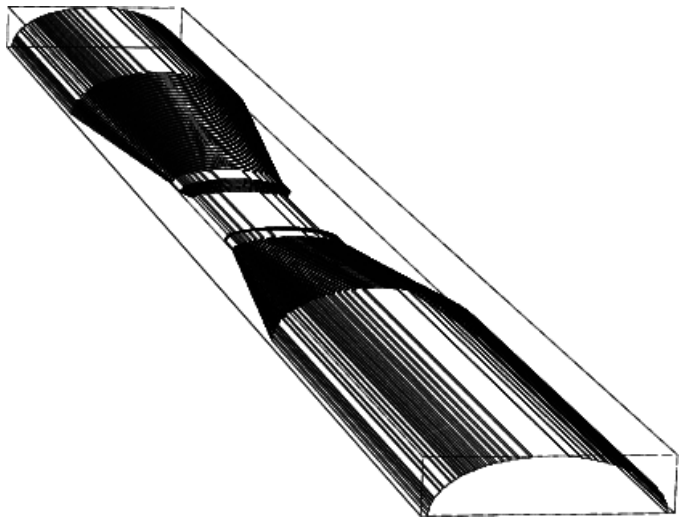
E-WAKE

H-WAKE

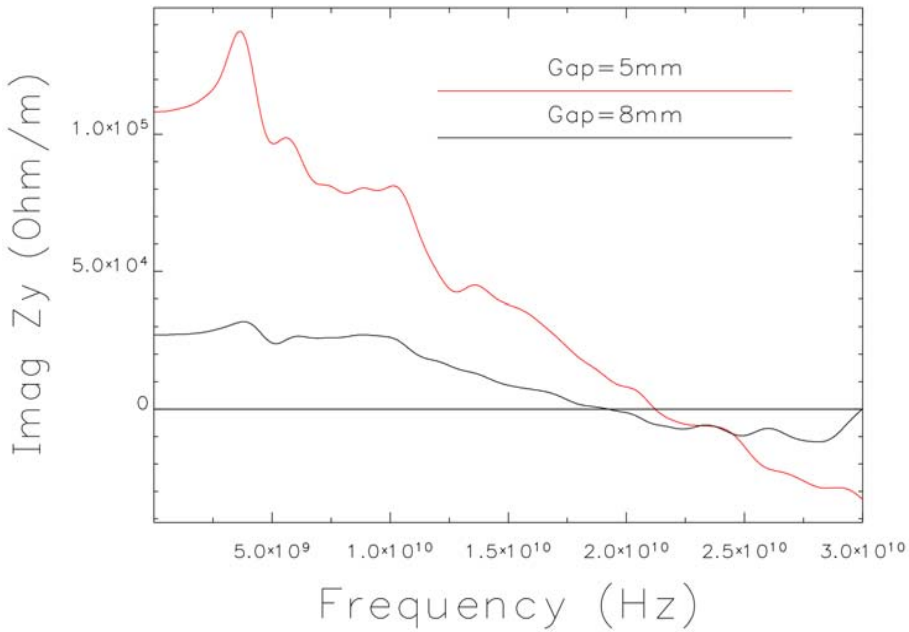


Impedance Database: Example

INSERTION DEVICE: VERTICAL

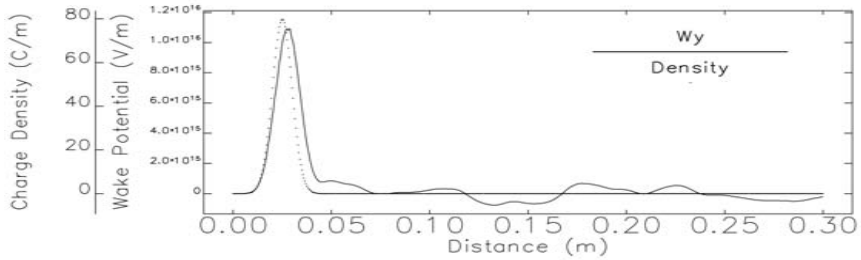


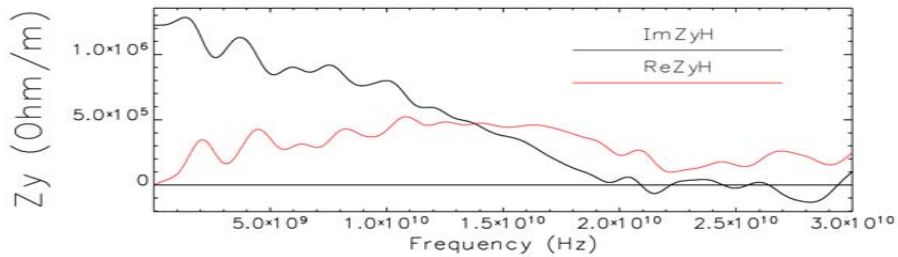
Geometry



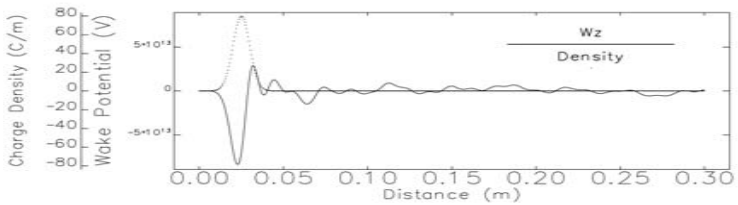
Impedance $\propto$ 1/b**3

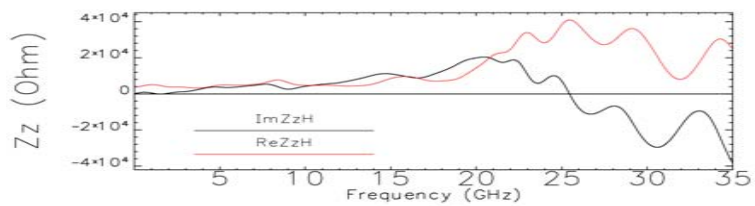
Impedance Database: Total



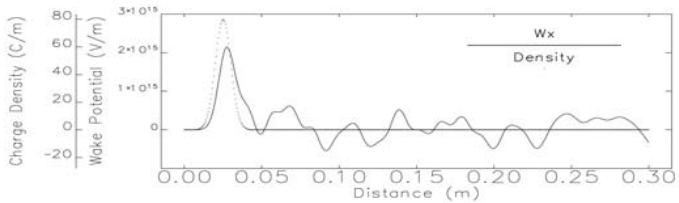


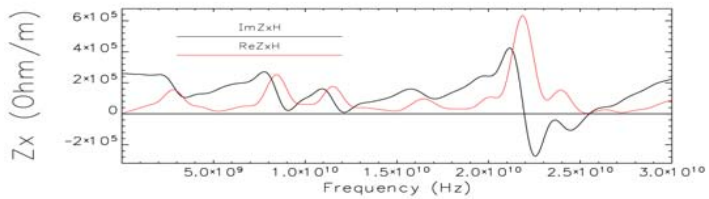
VERTICAL





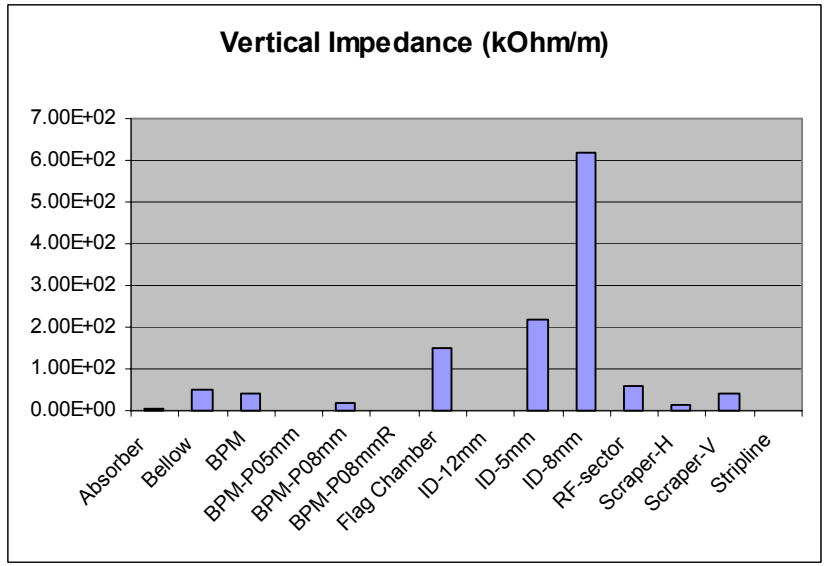
LONGITUDINAL

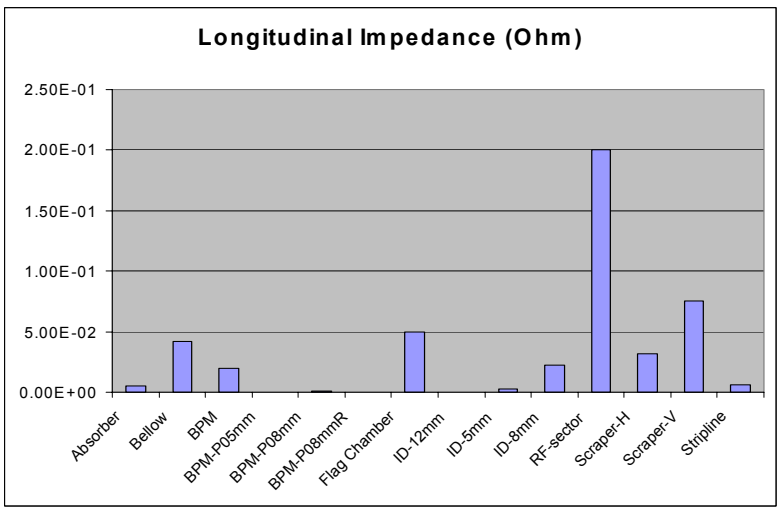


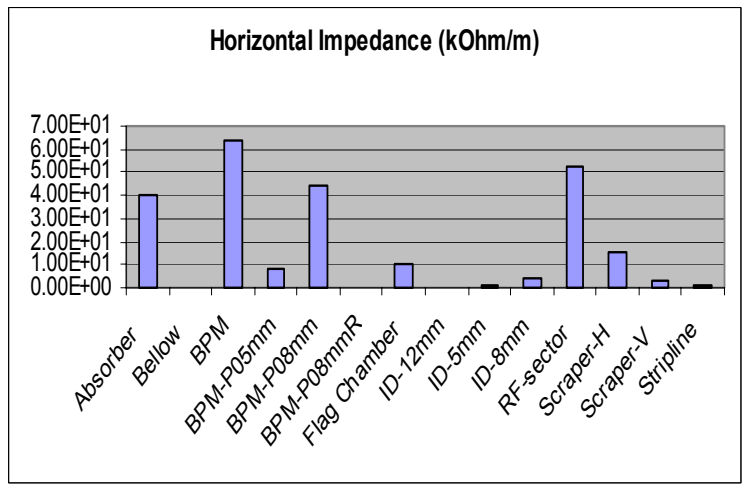


HORIZONTAL

Impedance Database: Total







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Application

Longitudinal Phenomena

- Microwave Instability
- Bunch lengthening and energy spread
- High azimuthal mode excitation (m=4)

Horizontal Phenomena

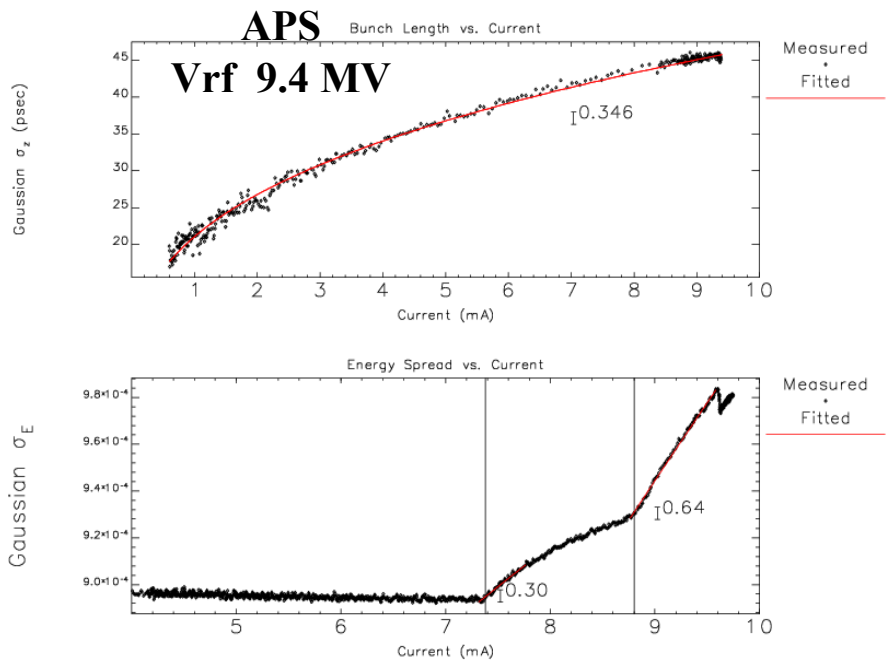
- Saw-tooth instability at low chromaticity

Vertical Phenomena

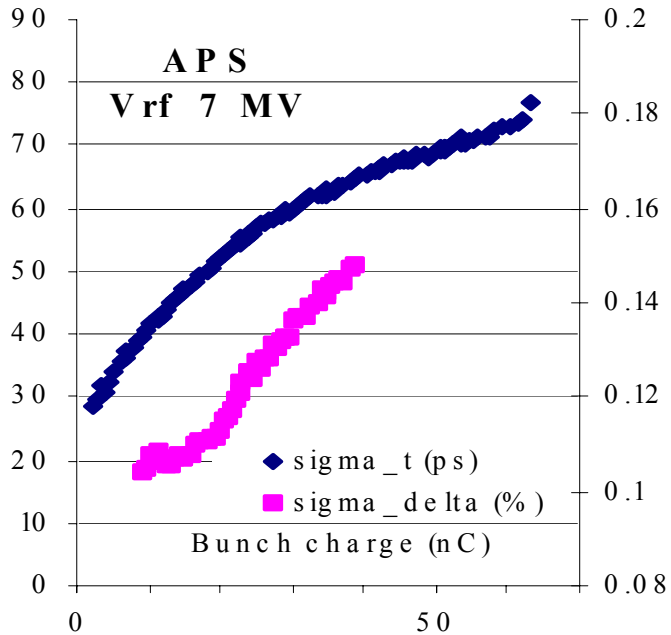
- Transverse mode coupling instability
- Mode coupling at 3 mA
- Stability limit at 5 mA
- Accumulation limit at 8-10 mA

Application: Longitudinal (Microwave Inst)

Measurement



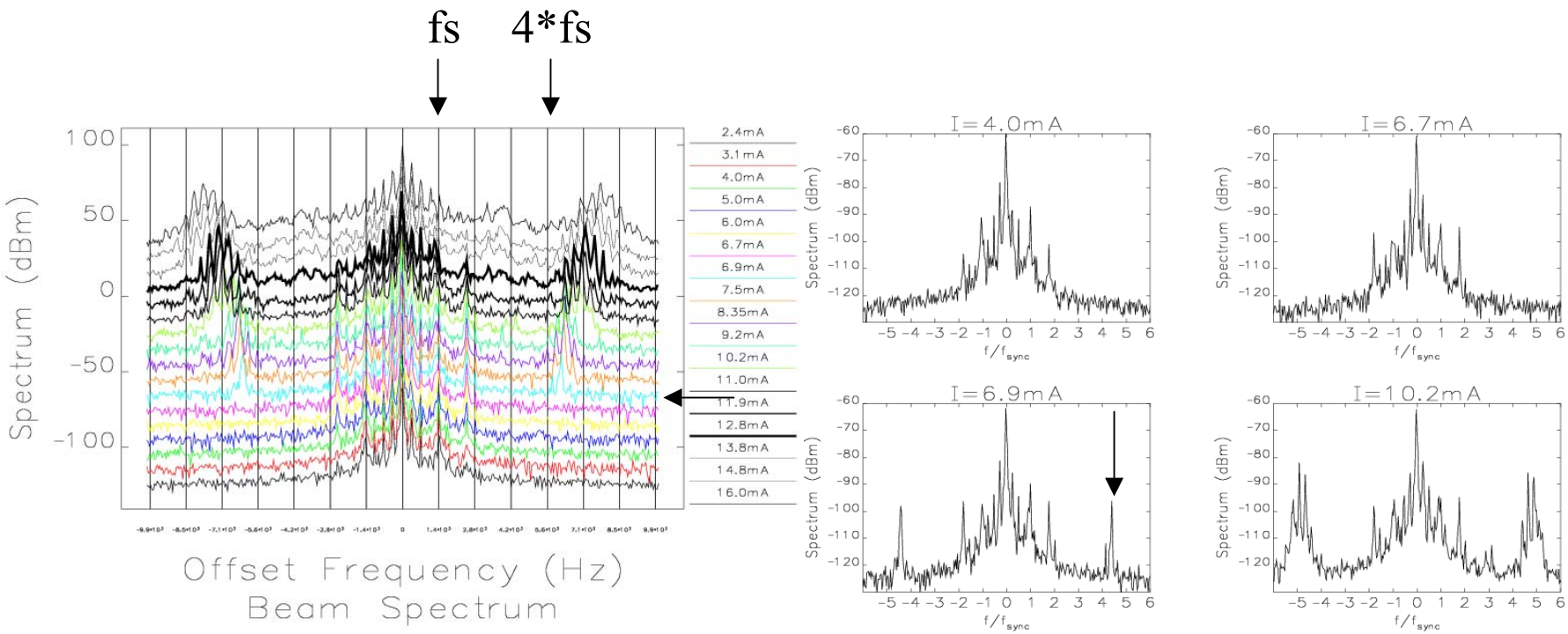
(Y.Chae, L.Emery, A.Lumpkin, J.Song, PAC'01)



(Courtesy of K.Harkay, B.Yang)

Application: Longitudinal (Microwave Inst)

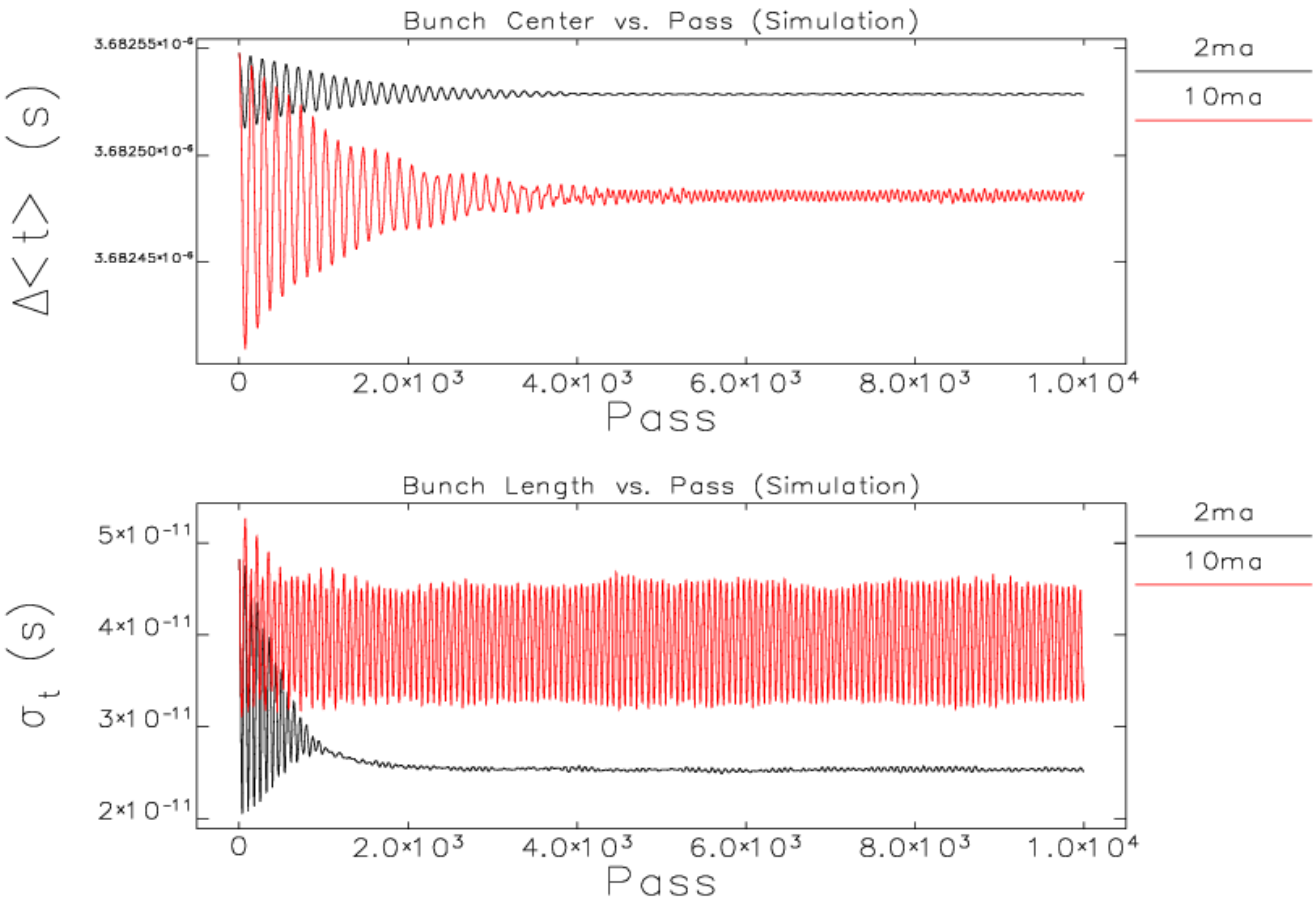
Measurement



(Y.Chae, L.Emery, A.Lumpkin, J.Song, PAC'01)

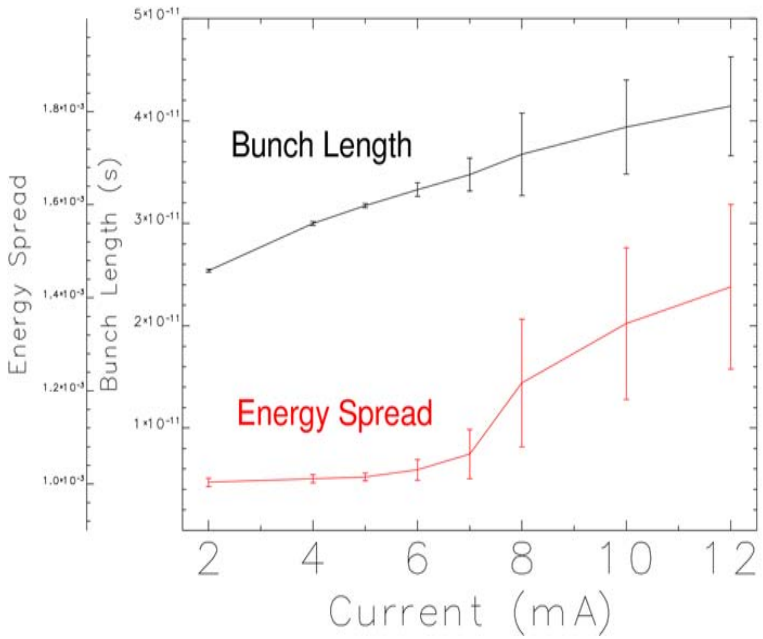
Application: Longitudinal (Microwave Inst)

Simulation

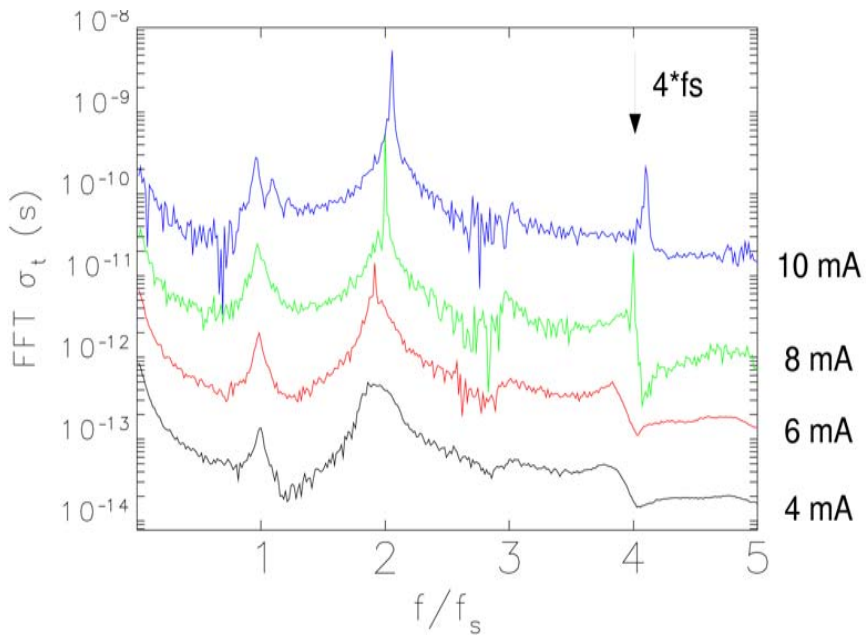


Application: Longitudinal (Microwave Inst)

Simulation



Bunch Length/Energy Spread

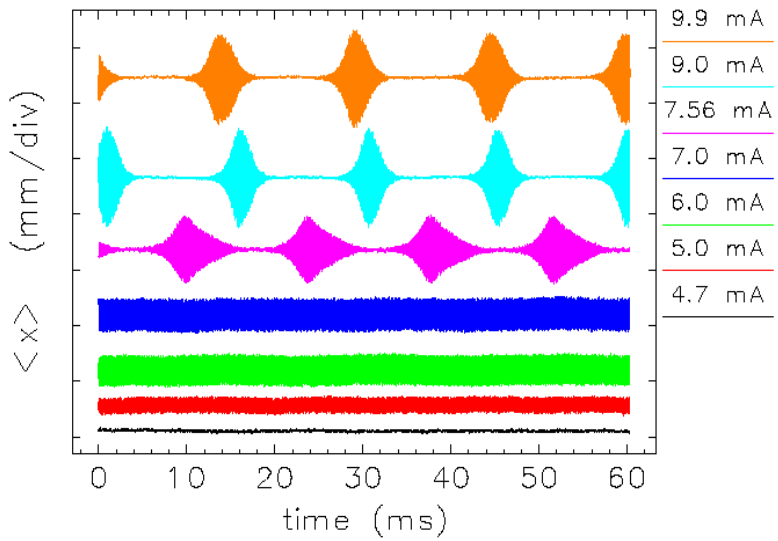


Bunch Length Oscillation

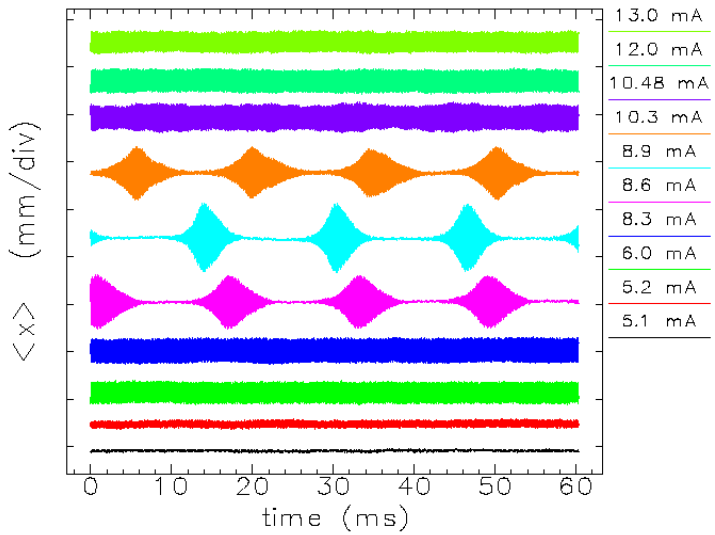
Application: Horizontal (Saw-Tooth)

Measurement

7.5 nm lattice, Vrf=9.4 MV



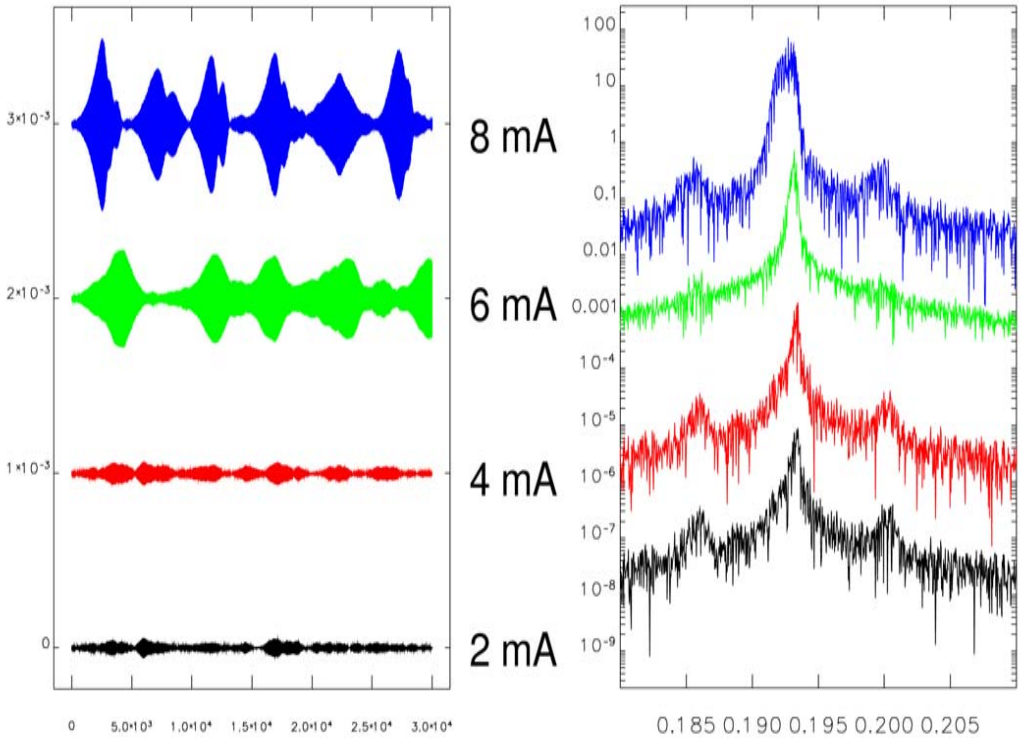
7.5 nm lattice, Vrf=7.0 MV



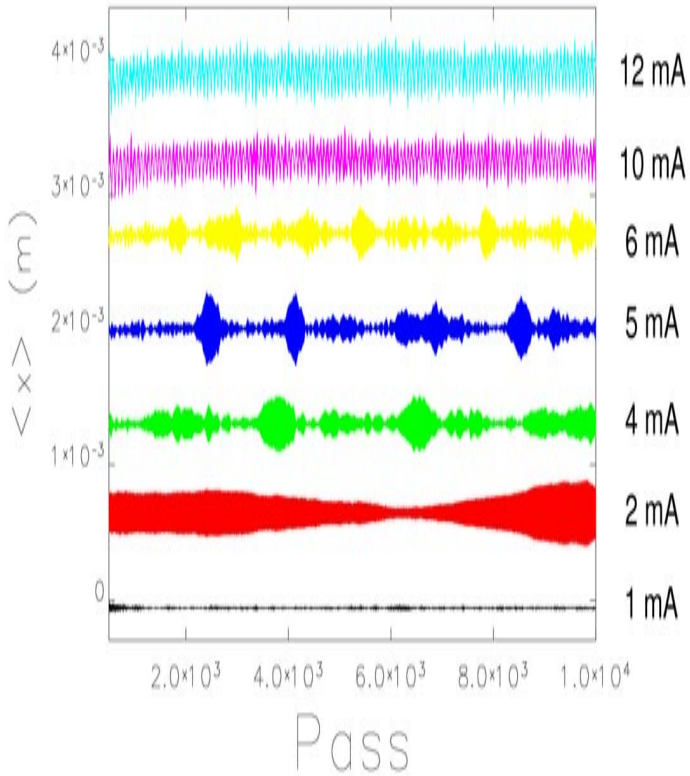
(Courtesy of K. Harkay, PAC'01)

Application: Horizontal (Saw-Tooth)

Simulation



Bursting mode excited by the narrowband impedance

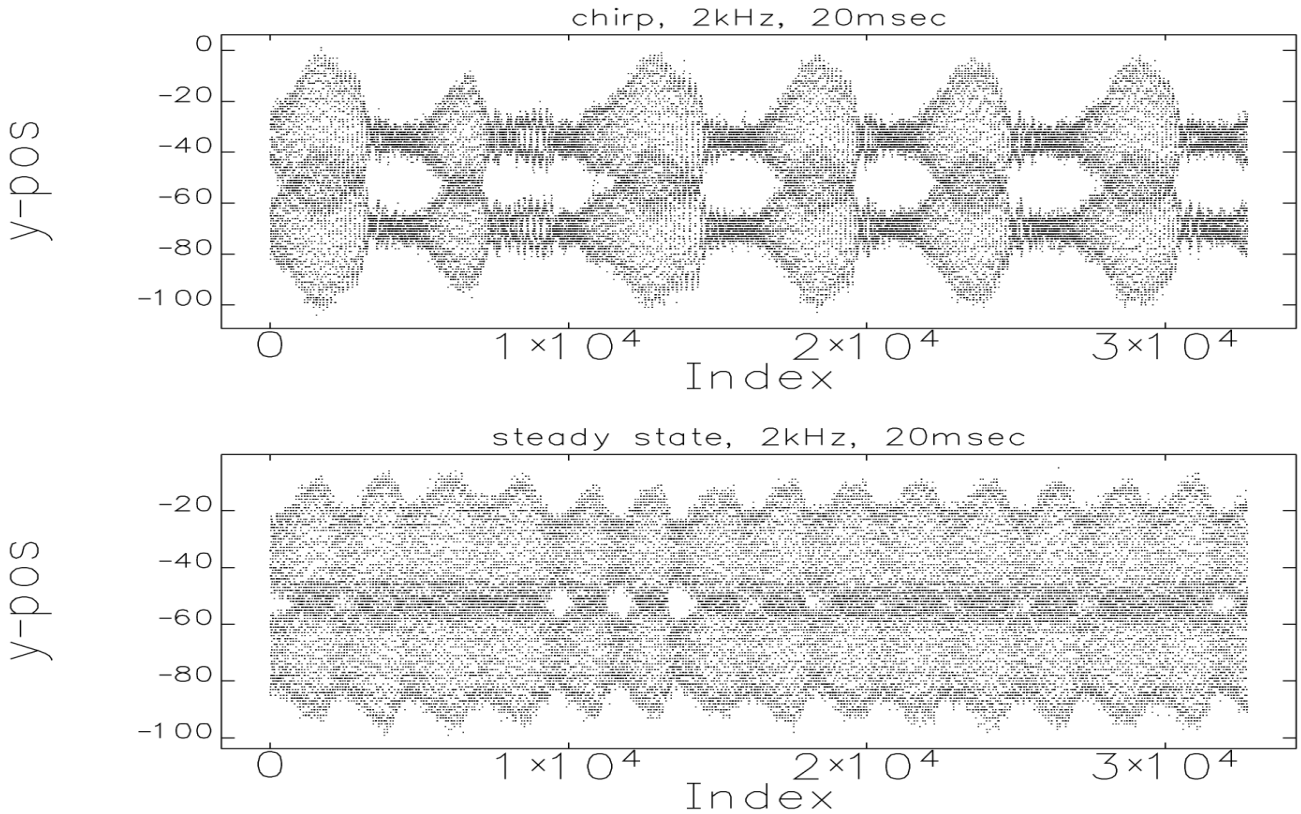


Bursting mode excited by the broadband impedance

Application: Horizontal (Saw-Tooth)

Measurement:Driving Beam Response

(C.Yao, Y.Chae, B.Yang, A.Lumpkin)

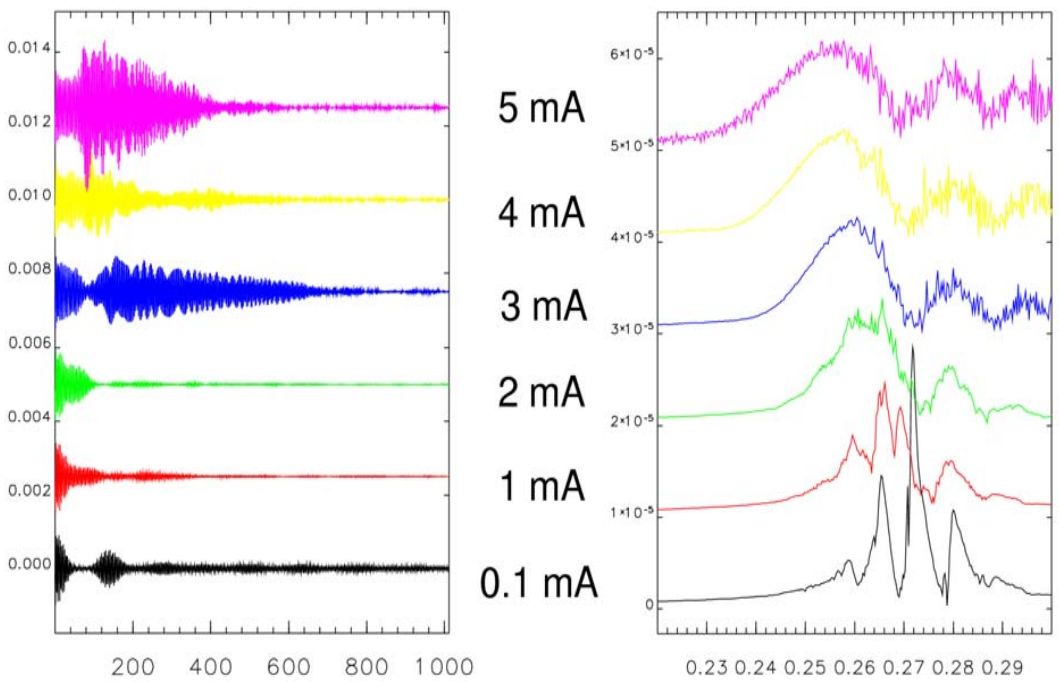


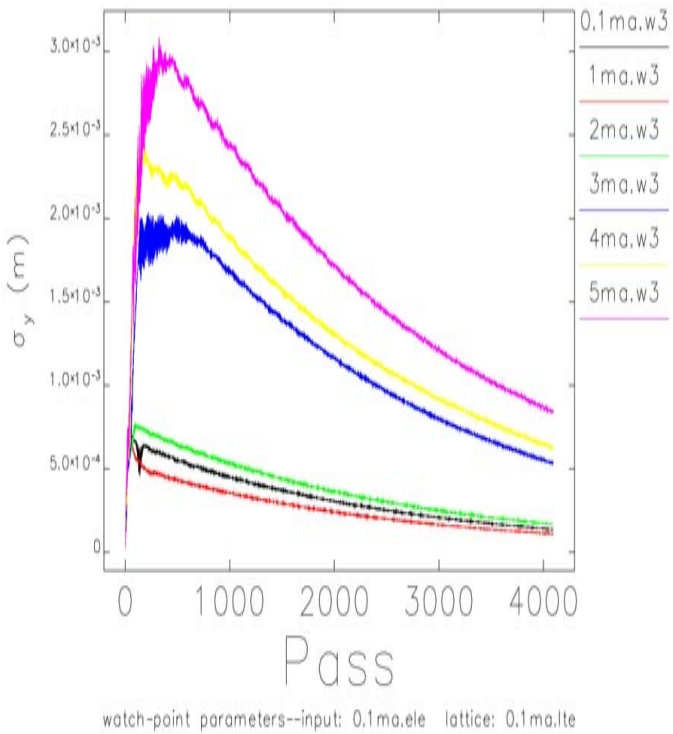
CHIRP

Steady State

Application: Vertical (TMCI)

Simulation



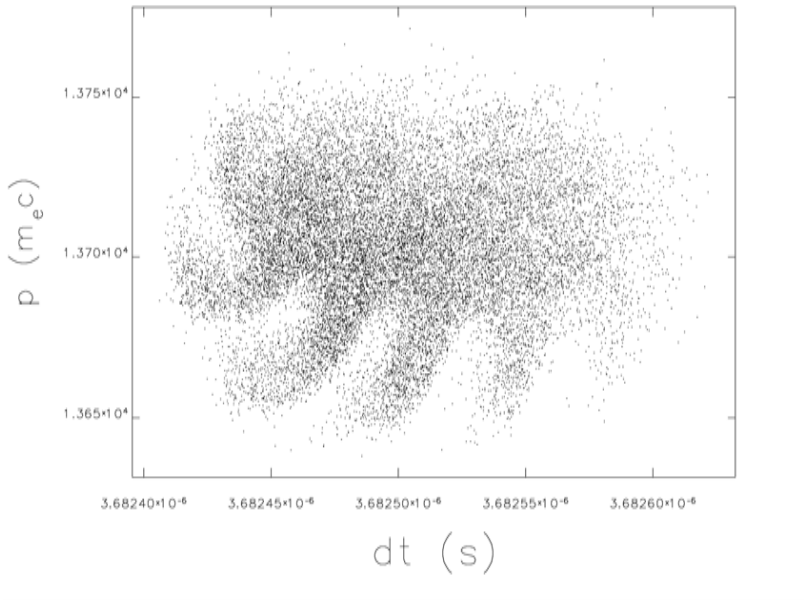


Discussion: Longitudinal (Microwave Inst)

1. Good agreement was obtained by impedance 80 % larger than the calculated total impedance

2. Bunch length oscillation could be verified by streak camera measurement

3. Sometimes we are getting this from the simulation:



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Discussion: Horizontal (Saw-Tooth)

1. Need to verify the source of excitation
   - Resistive wall
   - HOM of rf cavities
   - Broadband impedance

2. Understanding driving-beam-experiment is important
   - Controllable source
   - Nonlinear effect
   - Damping effect

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Discussion: Vertical (TMCI)

1. Current Situation
   - 24 x 8-mm and 2 x 5-mm chambers installed in the ring
   - Zy = 1 MΩ
   - Mode coupling at 3 mA and stability limit at 5 mA

2. Worst Situation
   - 34 x 5-mm chambers installed in the ring
   - Zy = 3.5 MΩ
   - Mode coupling at ~1 mA and stability limit at ~1.5 mA

3. Reduce the Impedance
   - 8 cm x 4 cm ➔ 2 cm x 5 mm (present)
   - 2 cm x 1 cm ➔ 2 cm x 5 mm (1/3 of the present Zy)
   - Optimize the taper ➔
     Linear vs. Polynomial or exponential (investigating)

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CONCLUSION

1. Initial construction of impedance database for the APS storage ring had been completed

2. Tracking study showed promising results

3. Realistic simulation should reveal the single bunch current limit in the future (not yet!)

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Acknowledgement

1. Collaboration with K. Harkay, X. Sun

2. Thanks to many people
   - S. Milton, E. Trakhtenberg from XFD
   - S. Sharma, L. Morrison from Mech Eng Group
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   - R. Soliday, L. Emery, M. Borland from OAG
   - G. Decker, O. Singh, A. Lumpkin, B. Yang, L. Erwin from Diag Group
   - V. Sajaev, C. Wang from Accel Phy Group
   - C. Yao from Operations Group