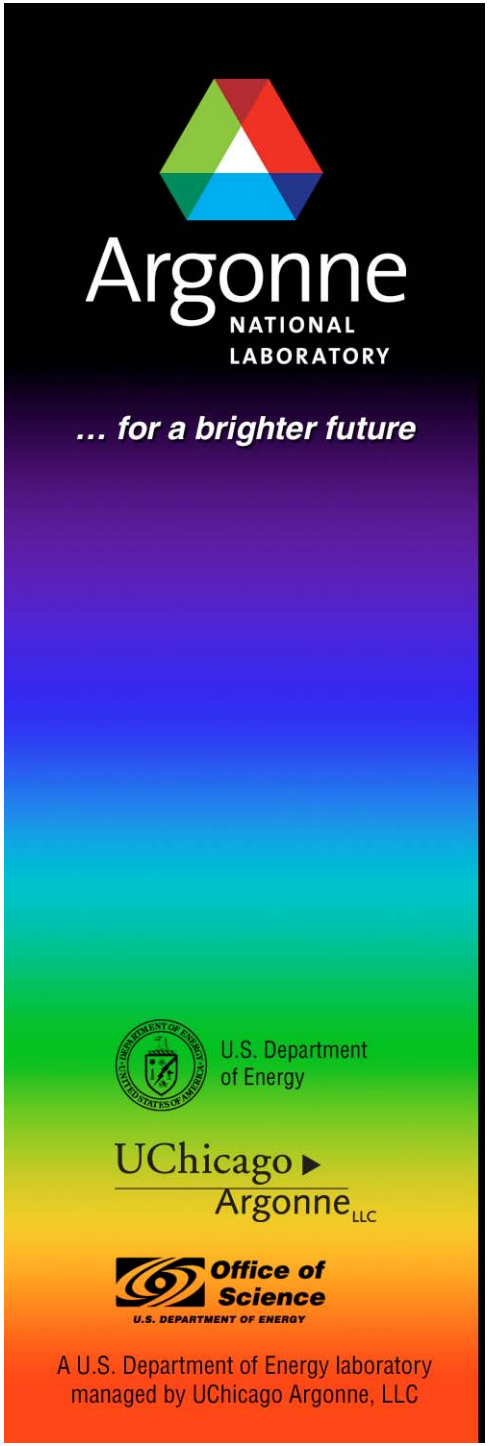


Instability Estimates for the APS Upgrade

Yong-Chul Chae

APS Upgrade MAC Review

November 15, 2006

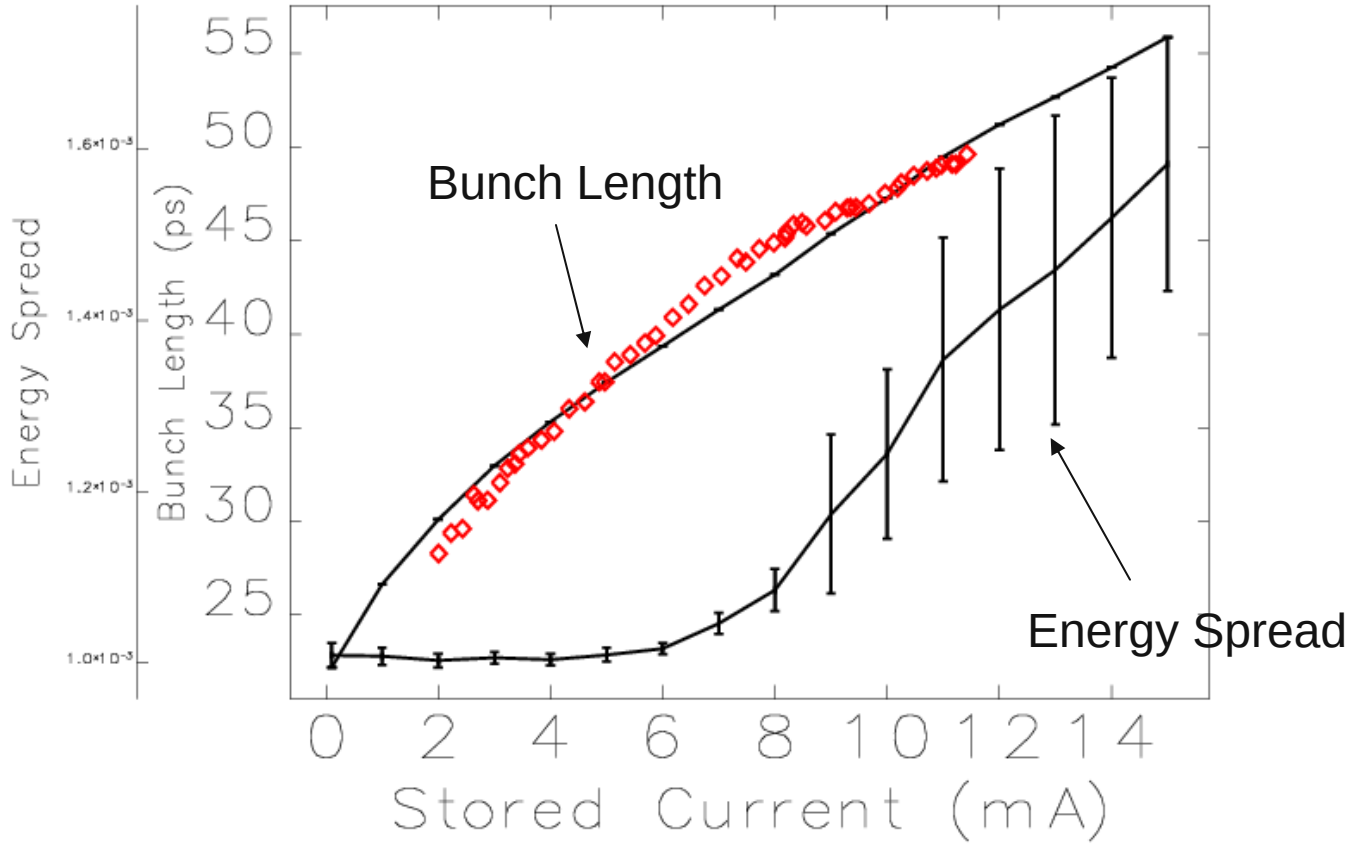
Outline

- Boundary Condition for the APS Upgrade Storage Ring
  - 16 mA in the single bunch
  - 200 mA in multiple bunches
- Single Bunch Instability
- Multibunch Instability
- Wakefield Issues Related to the ERL Option

Single Bunch Instabilities in the APS

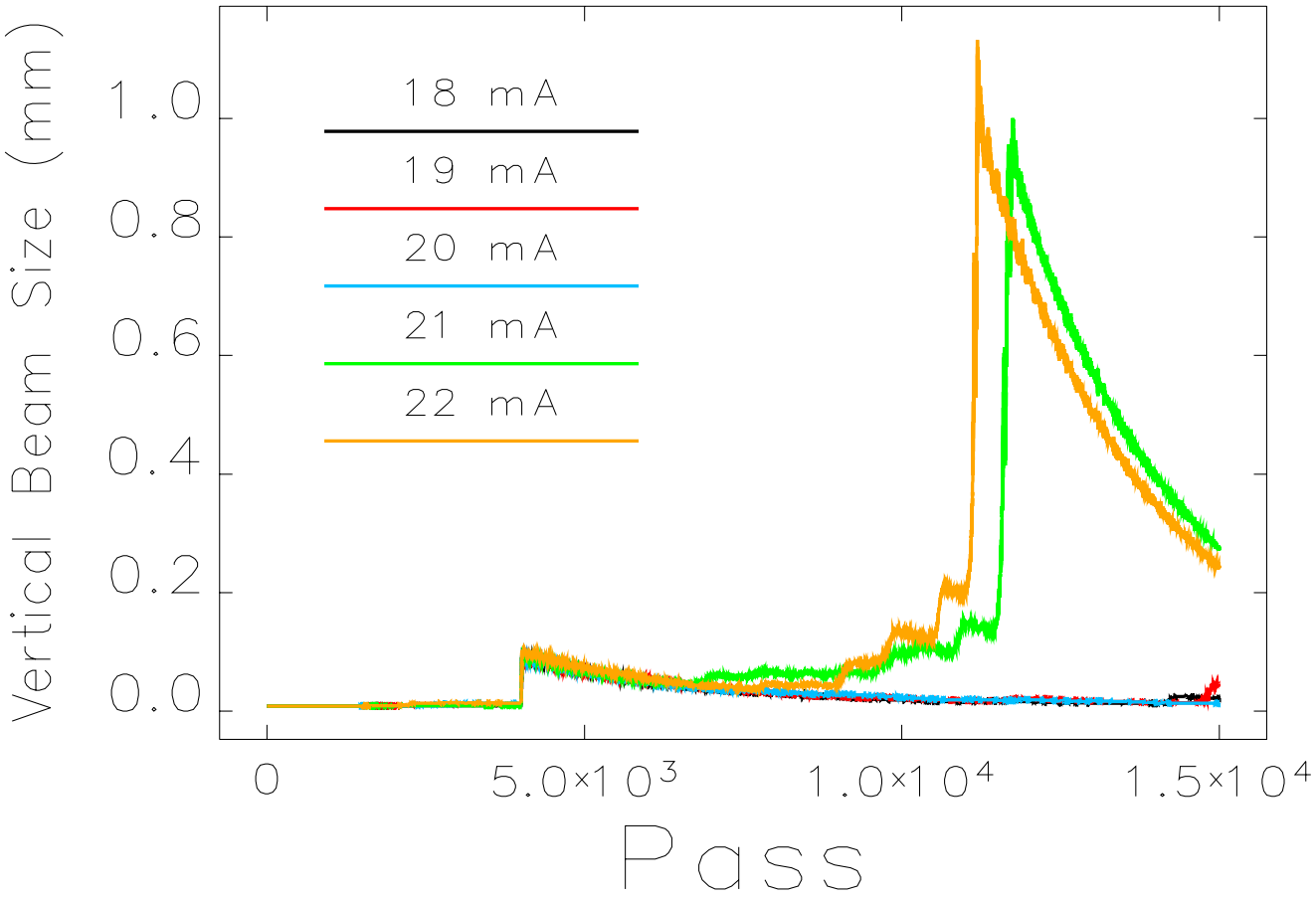
- Horizontal Sawtooth Instability
  - Repeats excitation-damping cycle with period of 10 ms
  - The instability will disappear at high chromaticity
- Longitudinal Microwave Instability (MW)
  - Increase the energy spread above the threshold current, 6 mA
- 5-mm Small Gap Chamber
  - Reduced the single-bunch current 20 mA to 8 mA by adding two 5-mm chambers to the ring
  - Knew that higher chromaticity can increase the limit
  - Chromaticity at 10 raised the accumulation limit to 20 mA
  - We deliver 16 mA for user run
- Instability became a serious issue because of the 5-mm chamber
  - Developed the elaborate impedance model
  - Set up multi-particle tracking simulation by using elegant
  - Found that Vertical TMCI limits the single-bunch current

Single Bunch: Microwave Instability in the APS



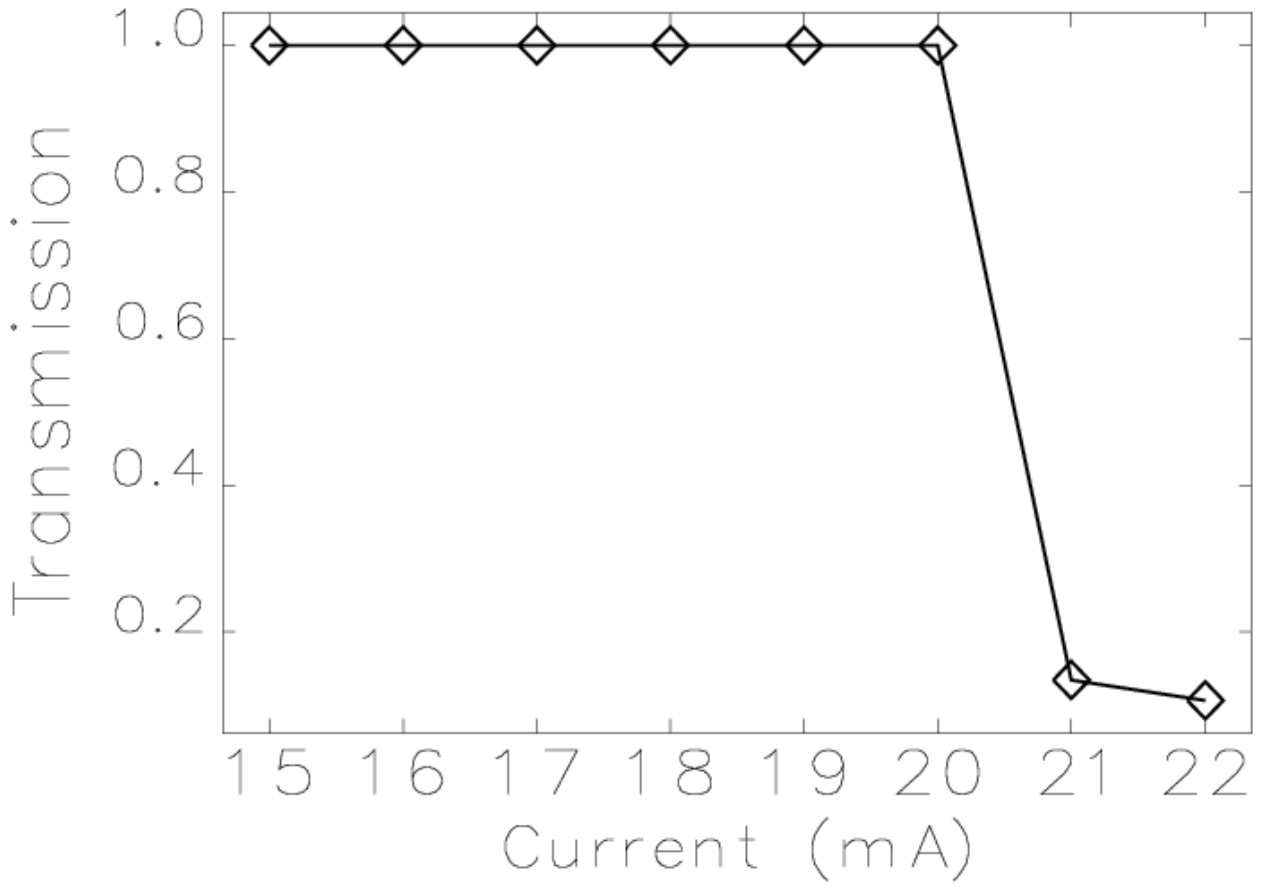
- Threshold current at 6 mA determined by simulation agrees well with the observed value in the APS storage ring.

Single Bunch: Simulation of Vertical TMCI at Injection



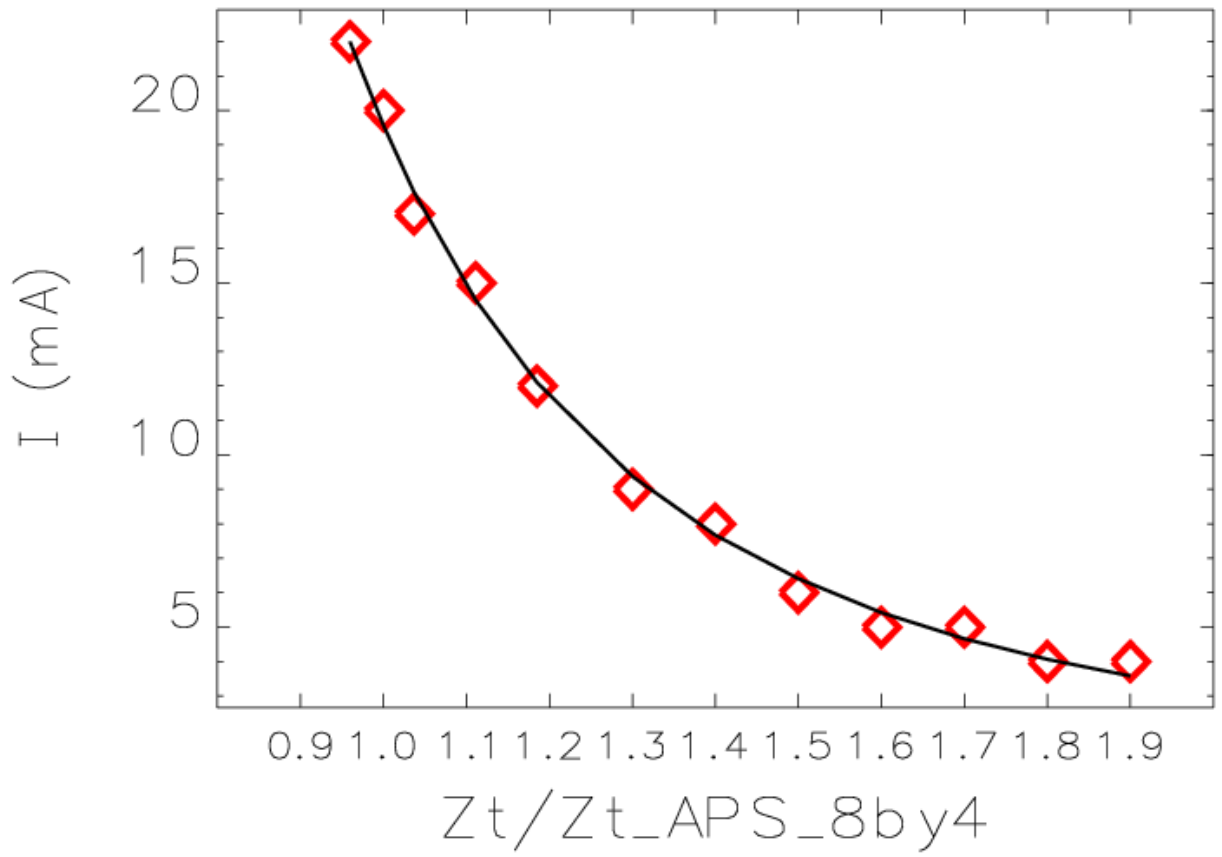
- Threshold current is 20 mA determined by simulation

Single Bunch: Accumulation Limit in the APS



- Simulation reproduced the accumulation limit at 20 mA observed in the APS storage ring

Single Bunch: Prediction for the APS



- We can now predict the effect of small-gap chambers

Single Bunch: APS Upgrade

- Strong focusing in order to achieve 1 nm
- Strong sextupole strength in order to correct chromaticity
- Small chamber in order to avoid saturation in sextupoles
  - 8 cm by 4 cm for APS-1 ➔ 4 cm by 2 cm for APS-2
- Increased impedance due to the small chamber, $1/b^3$ ➔ factor of 8!
- Can we store 16 mA in the single bunch?

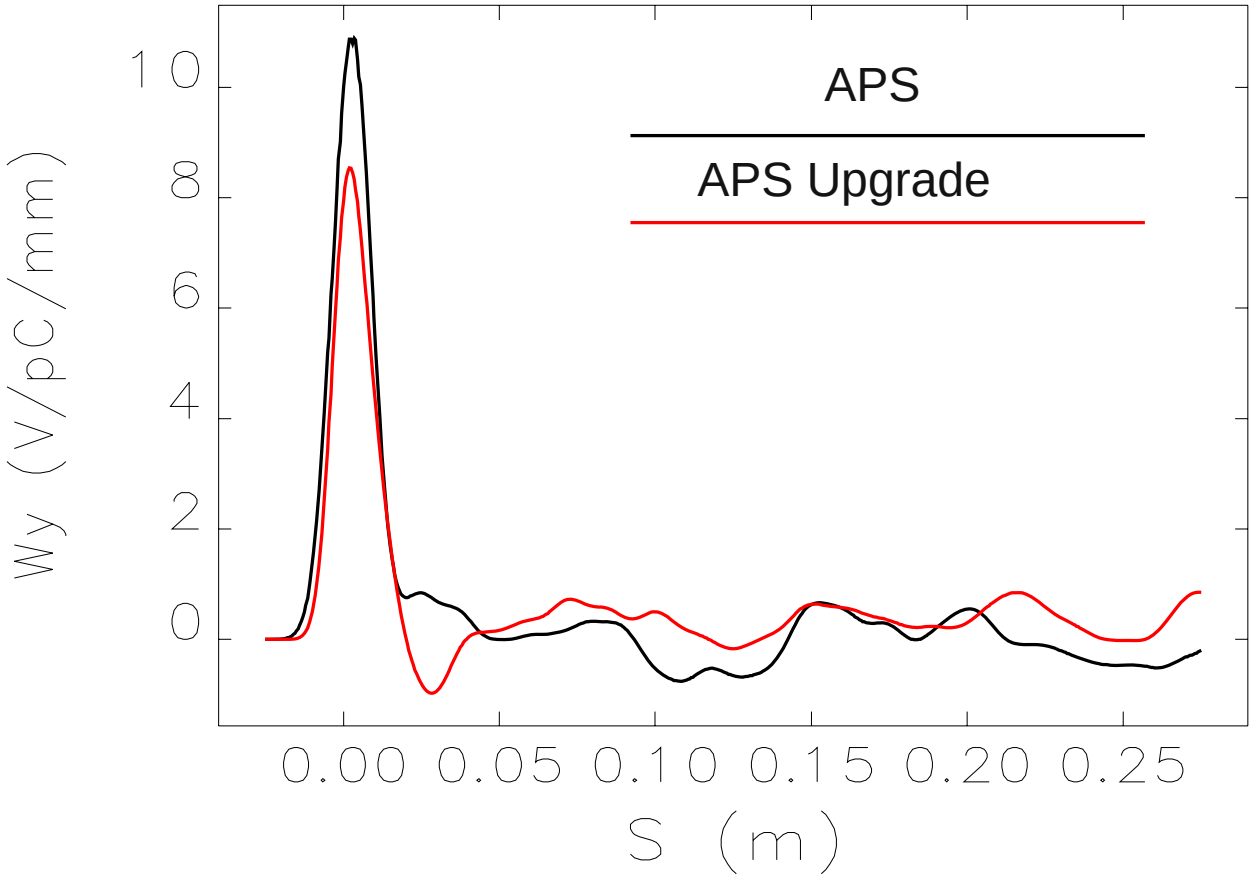
Single Bunch: Impedance Database for the APS Upgrade

- Assume that the cross-section of a regular vacuum chamber is 4 cm x 2 cm in ellipse

- Re-use the existing APS design
  - Transverse dimensions reduced by factor of two
  - Longitudinal dimension unchanged
  - Slopes of transition were reduced in many cases!

- Used GdfidL in place of MAFIA for wake potential calculation

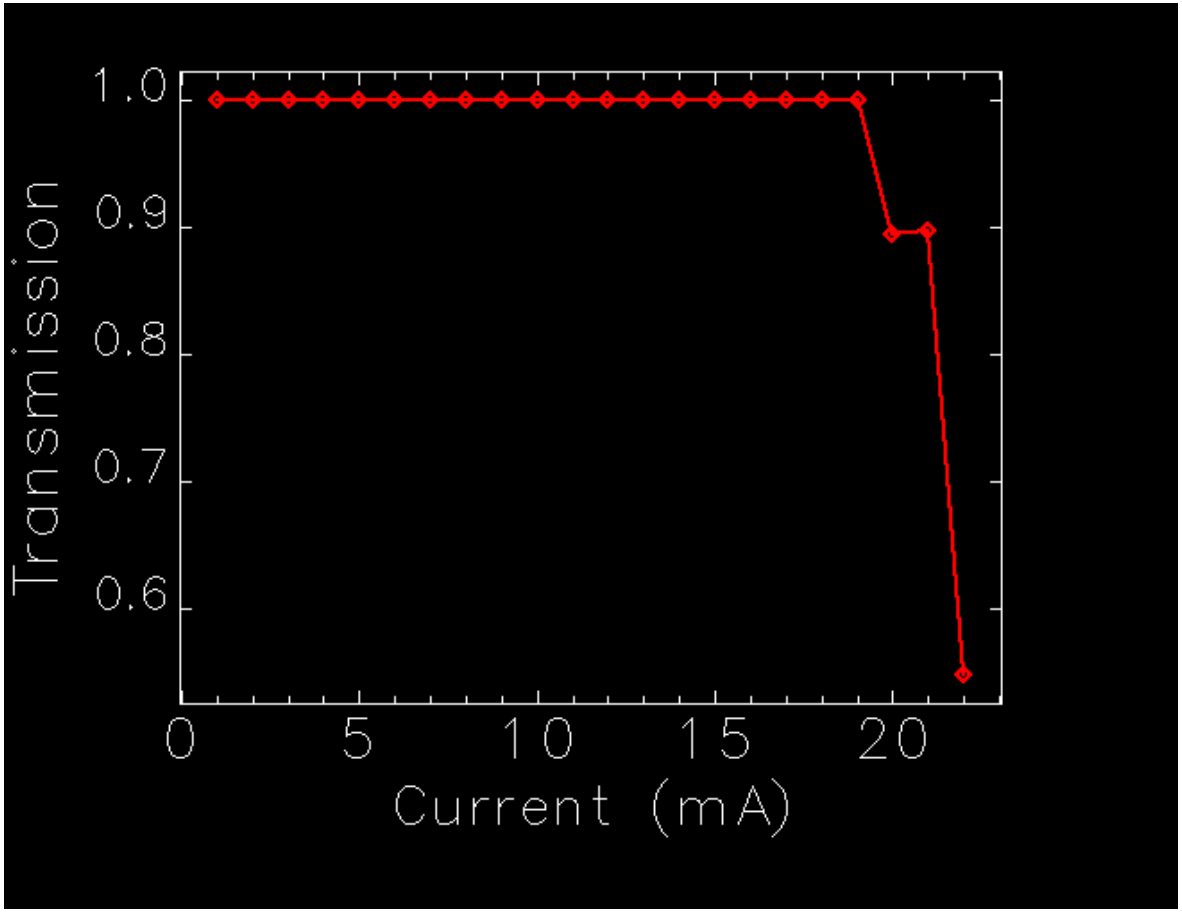
Single Bunch: Total Wake Potentials (Vertical)



- Assumption: No 5-mm gap chamber in the APS Upgrade

Single Bunch: Accumulation Limit in the APS Upgrade

- Assume 1-nm lattice for the simulation

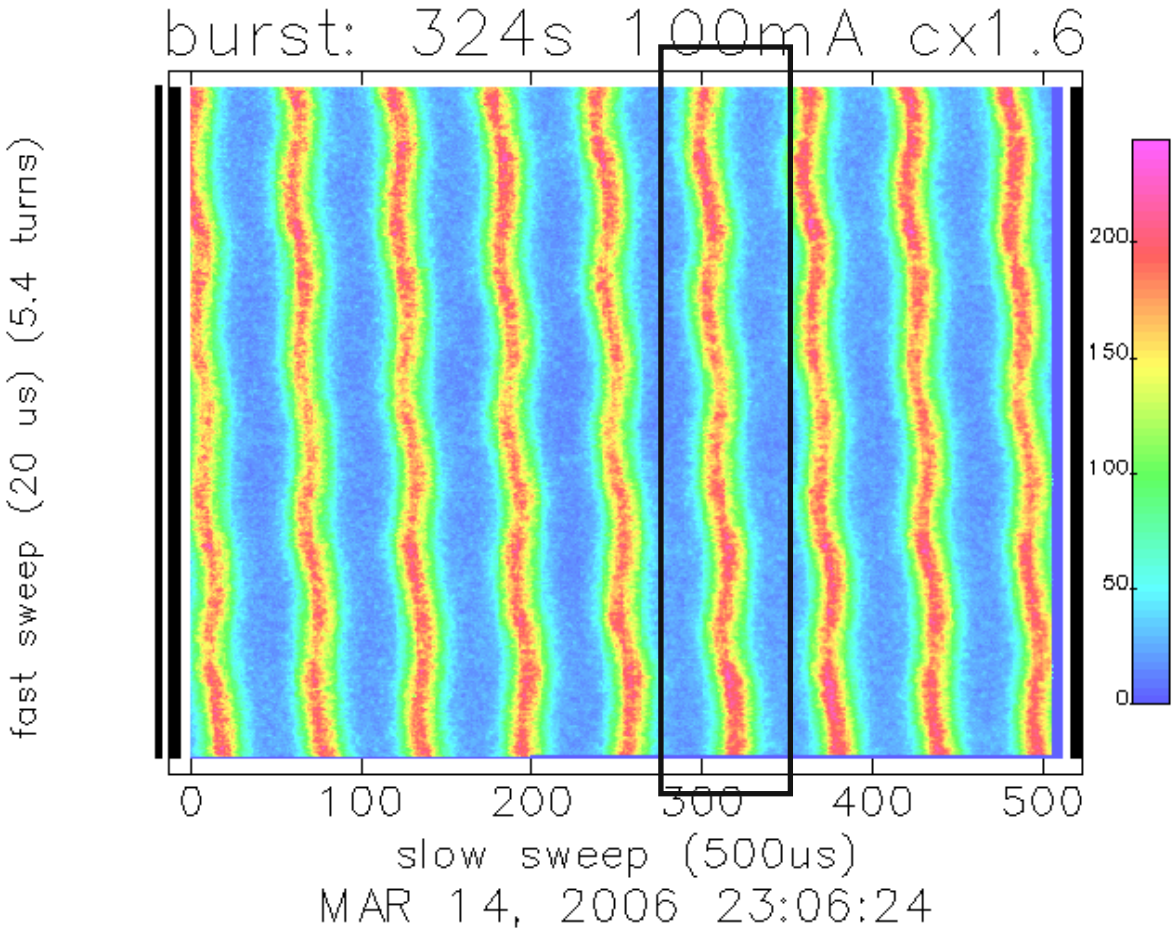


- Find that the accumulation limit is 19 mA

Single Bunch: Instability Estimate Summary

- Impedance of the APS Upgrade will be slightly smaller than the APS
- Microwave instability will start at 6 mA
- Accumulation limit will be 19 mA
- We find that we can deliver 16 mA for user run in the APS Upgrade

Multibunch: APS



- Instability Image (courtesy of K. Harkay)

Multibunch: APS Experience

- Coupled-bunch instability (CBI) observed mainly in horizontal plane
  - Occurs at low chromaticity but cured by raising chromaticity
  - No m=1 rf HOM modes excited
  - Source of instability is resistive wall impedance of 5-mm and 8-mm gap chamber

- Coupled-bunch instability observed also in longitudinal plane
  - HOM at 540 MHz is most dangerous in 24 bunch modes
  - HOM damper installed at Sector 38 raised to at least
    - *164 mA in 24 bunch mode limited by heating*
    - *245 mA in 324 bunch mode limited by CBI*

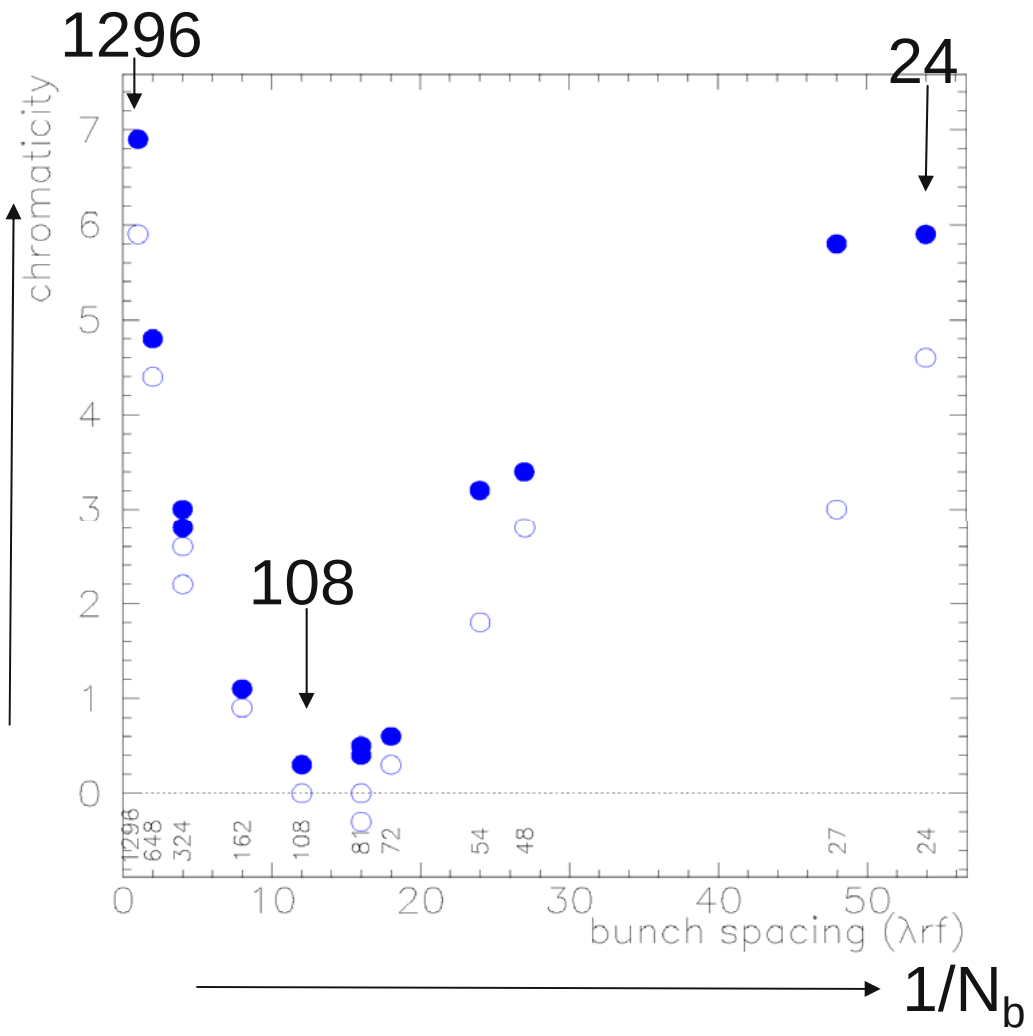
- 200 mA in the APS is achieved
  - K. Harkay, A. Nassiri, M. Borland, L. Emery *et al.*

Multibunch: Route to 200 mA in the APS Upgrade

- Utilize the experience we gained from the APS 200 mA operation
- Reduce Ohmic heating by redesigning vertical scraper and HOM damper
  - Scrapers optimized for small energy loss
- Implement the bunch-by-bunch feedback system
  - P0-bunch feedback system under development
  - 200 MHz Bandwidth and 600 W power
  - Enough to damp couple-bunch instability of 24-bunch mode
- Optimize the fill pattern for low chromaticity operation
- Make the vacuum chamber symmetric in the horizontal plane

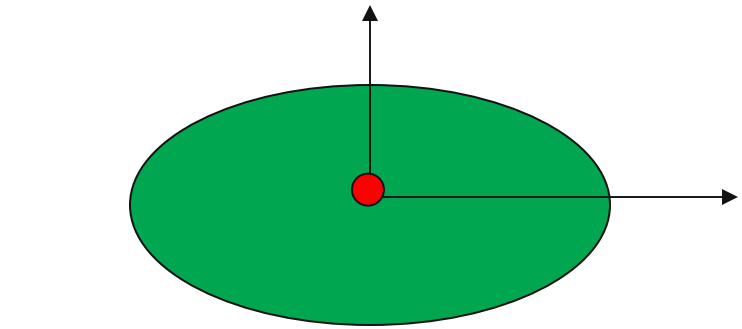
Multibunch: Fill Pattern Optimization

Chromaticity for Stability



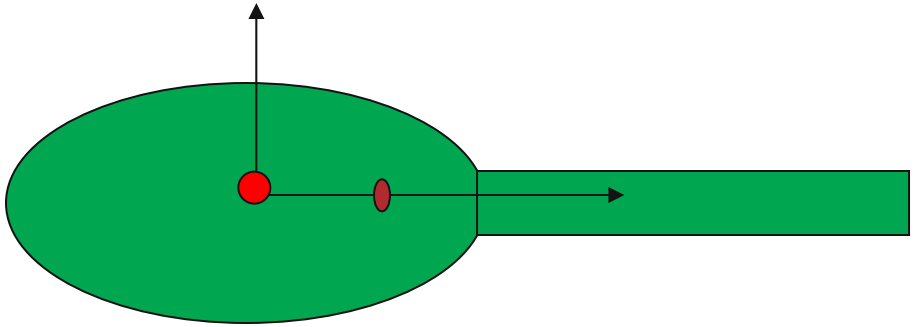
- Figure courtesy of K. Harkay

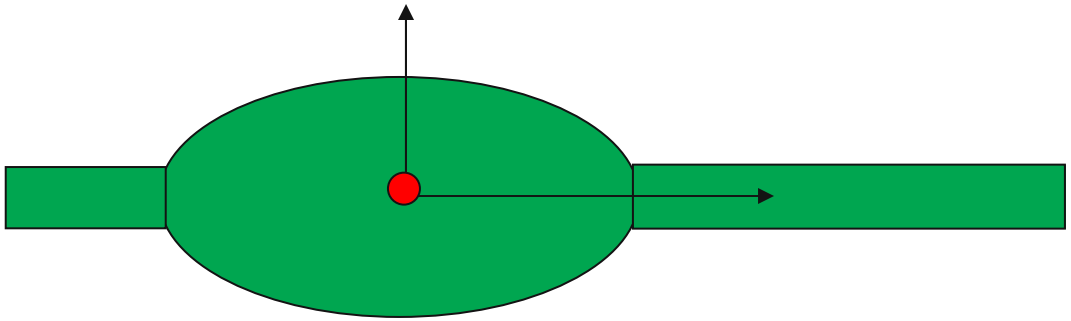
Multibunch: Symmetric Vacuum Chamber



Ideal Chamber

APS-I Small Gap Chamber





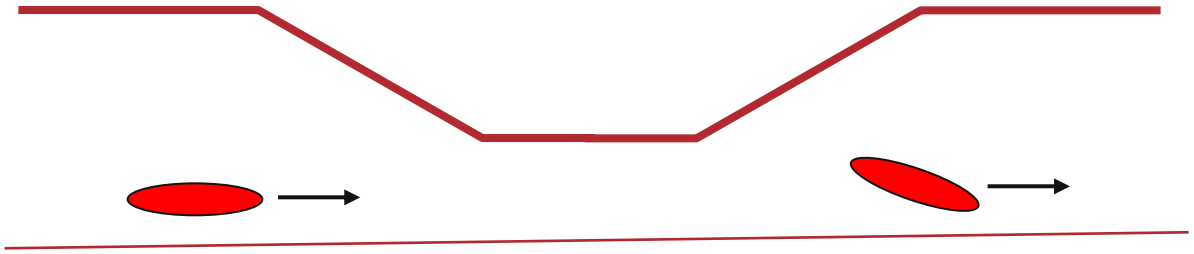
Symmetric Chamber

Multibunch: Instability Estimate Summary

- The APS had achieved 200 mA milestone
- By taking advantage of this experience we should be able to store 200 mA or more in the APS Upgrade
- We don’t anticipate a major problem to achieve the goal

Issue and Plan for ERL Option

- Storage ring becomes a beamline with 30-40 small gap chambers



- International Linear Collider (ILC) estimated that the wakefield generated by 1-ps bunched beam at the collimators could be significant
  - Collimator gap = 4-8 mm in ILC

- Need to estimate the wakefield of the 100-fs bunched beam through small gap chambers in the APS Upgrade

Issue and Plan for ERL Option (2)

- Accurate numerical calculation of wakefield for 100-fs bunch will be very difficult or impossible with the existing low-order accuracy codes
  - Serial version of MAFIA
  - Parallel version of GdfidL

- Decided to develop high-order accuracy 3D EM code through international collaboration
  - APS is leading collaboration with MCS, KEK, and Brown U. to develop a Spectral Element Method based wakefield code through LDRD
  - APS is pursuing collaboration with TechX to develop a Finite Difference Method based wakefield code through DOE/BES SBIR

- Optimize the small gap chamber in order to reduce the wakefield effect
  - Join the ILC's international collaboration on collimator design

Summary

- We estimate that in the APS Upgrade storage ring
  - The single-bunch current limit will be above 16 mA
  - The total current will be 200 mA
- Small-gap chamber will be optimized for the wakefield effect by a high-order accuracy code through the international collaboration
- We will continue to investigate any possible show-stoppers to meet the goal of the proposed APS Upgrade