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Operations with Fast Digital Orbit Feedback Systems at NSLS

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Outline

- Introduction
- NSLS System Design
- NSLS System Performance
- Challenges and Future Work
- Conclusion

Relevant NSLS Ring Parameters

Parameter	UV	X-ray
Energy	800 MeV	2.8 GeV
Orbit Circumference	51 m	170 m
Horizontal/Vertical Tunes	3.1 / 1.3	9.8 / 5.7
Typical beam size, H/V	500 / 200 µm	200 / 50 µm
Lifetime	5 hrs	13-25 hrs
Nominal duration of a fill	5 hrs	12 hrs
Number of correctors H/V	16 / 16	56 / 40
Number of BPMs H/V	24 / 24	48 / 48
Typical corrector BW H/V	60/30 Hz	60 /30 Hz

Motivation and History

- Environmental noise on the beam
  (Booster, Floor Vibrations, 60 Hz Harmonics, etc.)
- Eliminate or Build a Feedback System
- NSLS efforts

  Late 80s: Analog local feedbacks in some of X-ray beamlines

  Late 80s: Analog global feedback system in UV and X-ray rings

  Mid-90s: Digital feedback test system development in X-ray ring

- "Old Digital Feedback System" at NSLS

  550 Hz sampling rate

  High gain but only ~15 Hz correction bandwidth

  Significant reduction in slow drift and 1.2 Hz booster noise

  Studies only; never put into operations

Clear advantage of going digital

Calculating Correction Values

Singular Value Decomposition of the Response Matrix

- Max # of Eigenvectors = Min(# of BPMs, # of trims)
- More Eigenvectors = Better Correction
- <u>But</u> as the # of Eigenvectors Increases

  Computation time increases

  More sensitive to errors at isolated BPMs

  May run into stability problems

New System: Design Trade-Offs

- Sampling Rate = 5 KHz

  Match the analog system BW

  No anti-aliasing filters

- Independent system vs. existing micros

  Could not get 5 kHz

  Development without interfering with operations

- Where and how to digitize:
  at BPM receivers vs. off-the-shelf ADCs in a VME crate)

  Noise

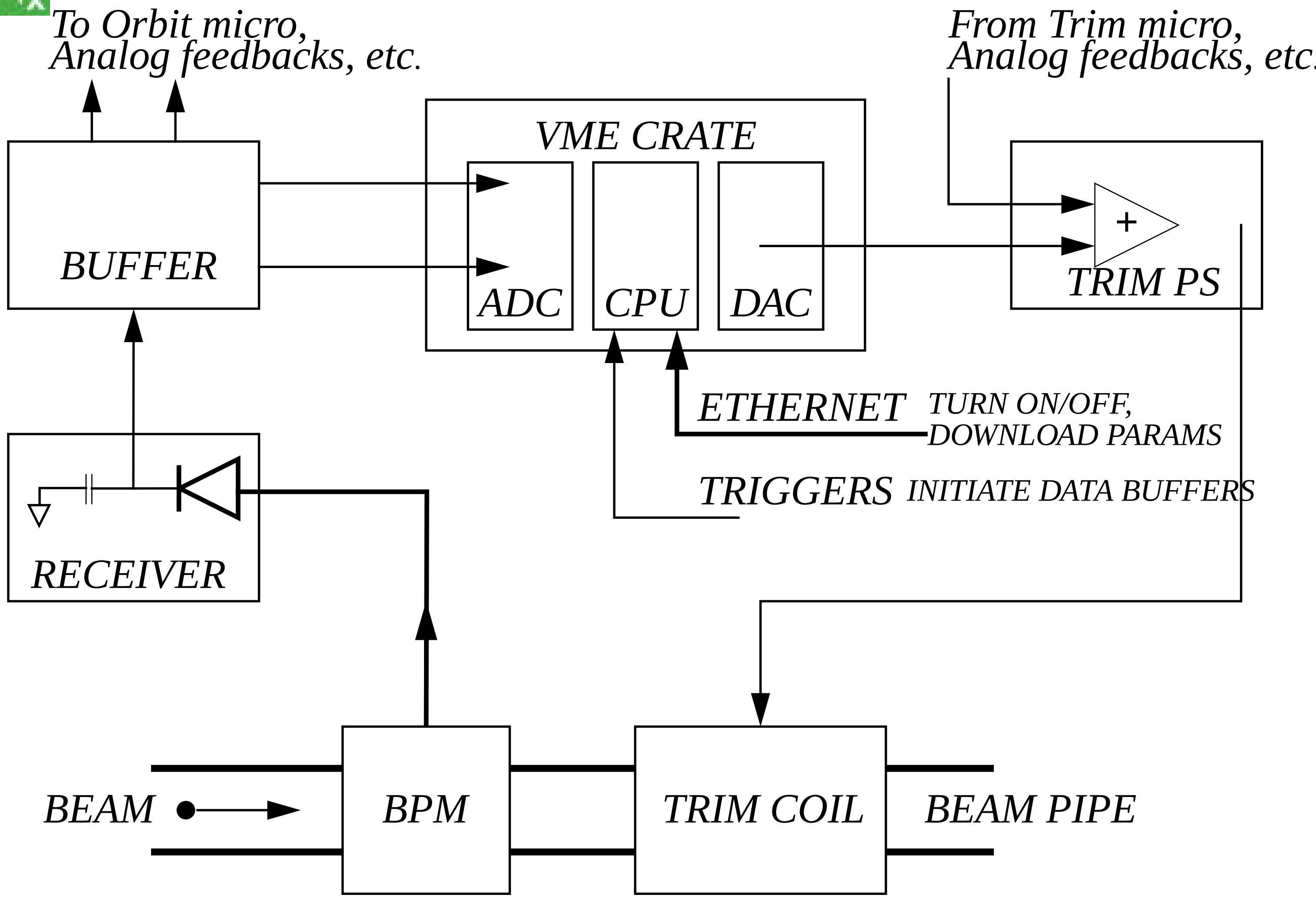
  Reliability in X-ray tunnel

  Proprietary design and development time

- Single board VME CPU vs. DSPs

  Mainframe expertise at NSLS

New System Layout



NSLS VUV Ring Digital Orbit Feedback System

Configuration

- VUV Ring (In Operations since Aug. 2000)

    Both planes in one system

    24 BPMs, 8 trims, 8 eigenvectors each plane

- X-ray ring (Vertical in Operations since Sept. 2002)

    One system per plane

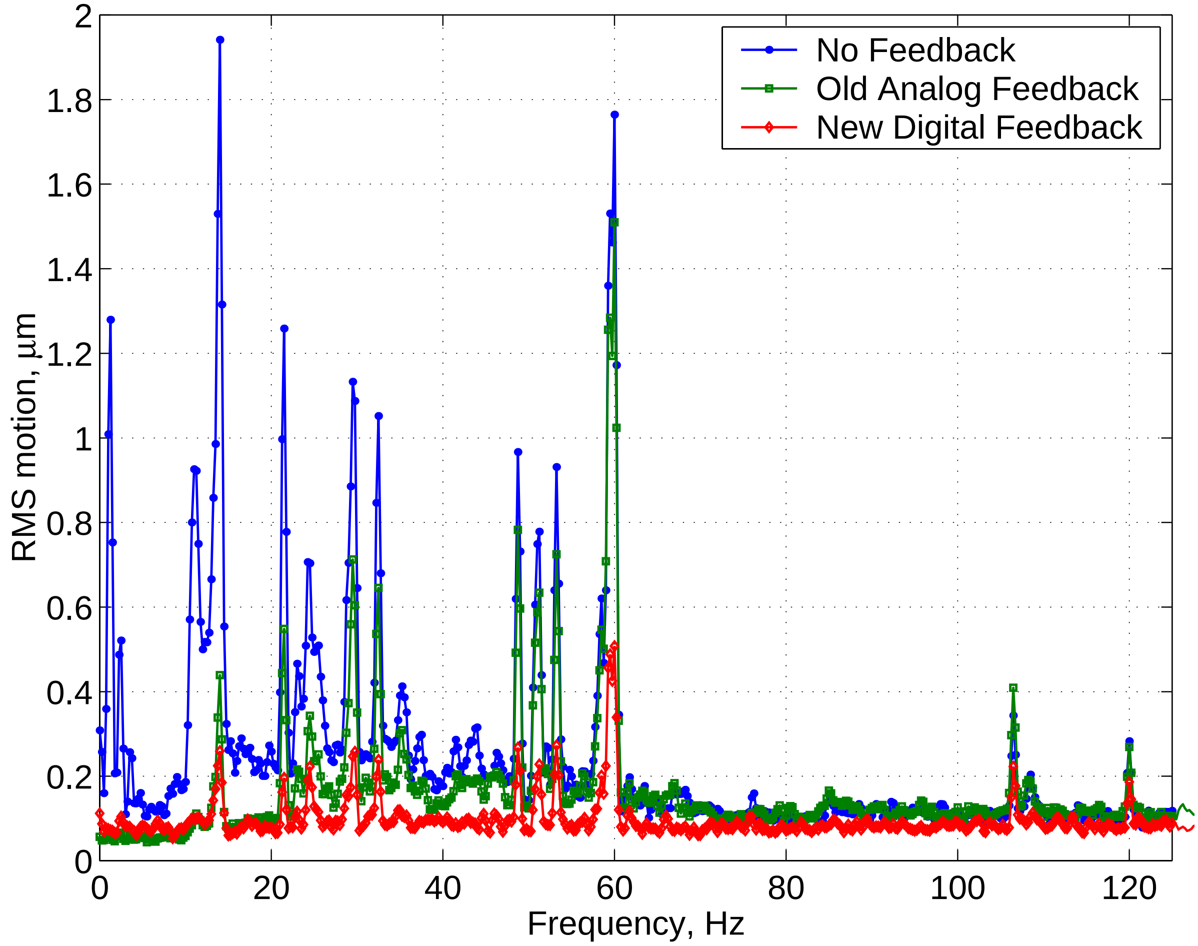
    Vertical:

    48 BPMs + 1 Photon Blade, 39 trims, 8 eigenvectors

    Horizontal (studies configs):

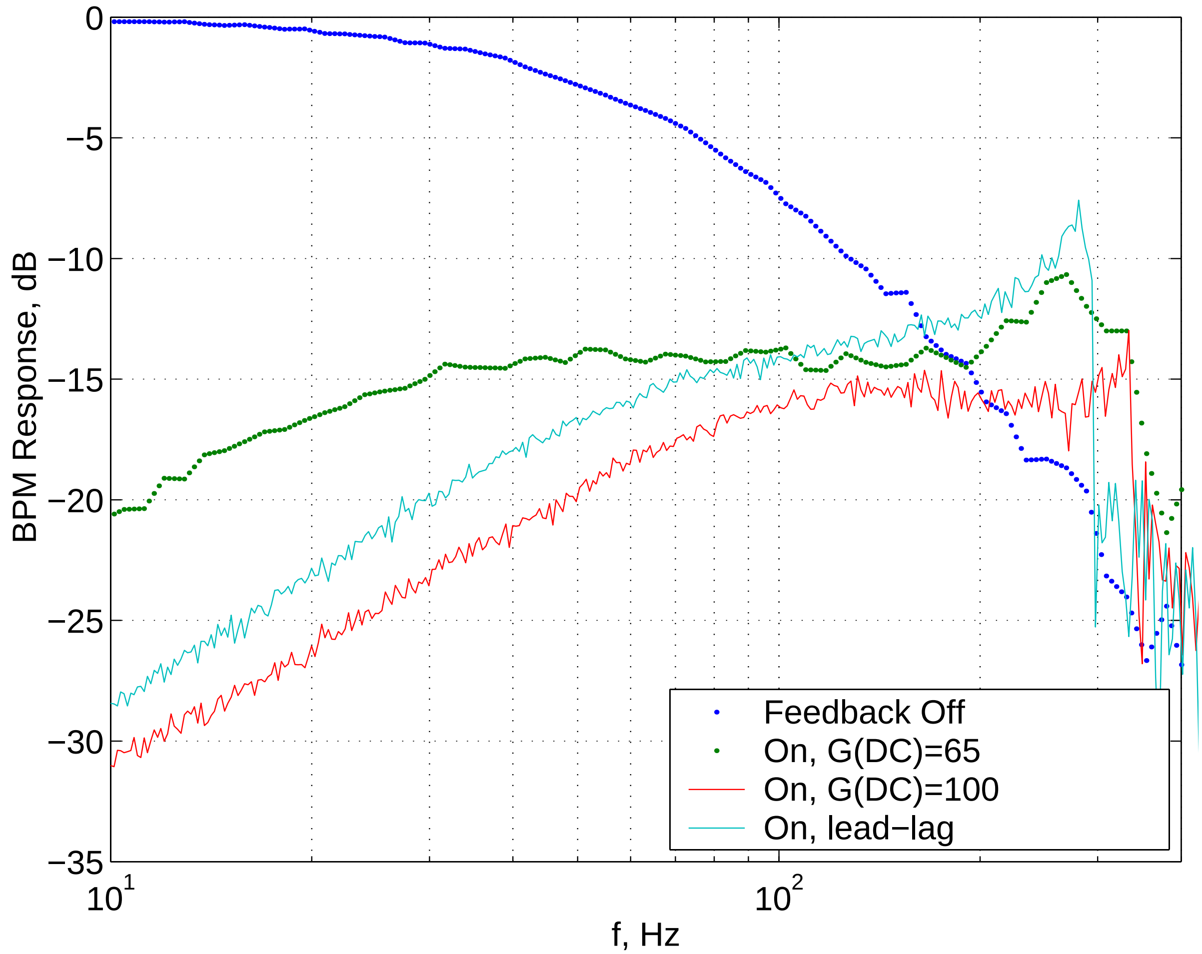
    48 BPMs + 1 Photon Blade, 39-55 trims,
    up to 16 eigenvectors

Orbit Noise Reduction



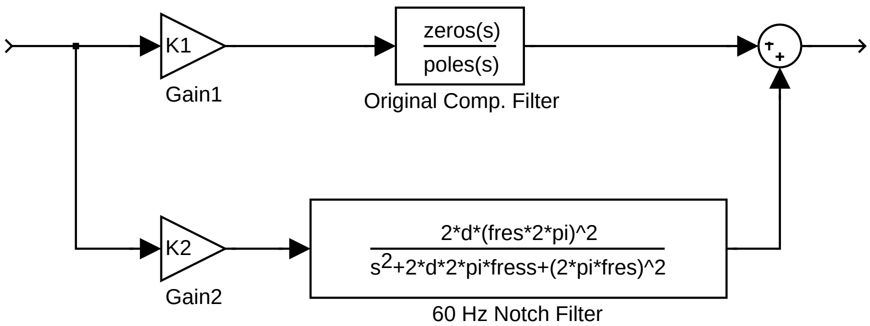
Frequency Response

<u>Setup</u>: Use a network analyzer; excite a vertical trim not used in the feedback; measure the response at a vertical BPM



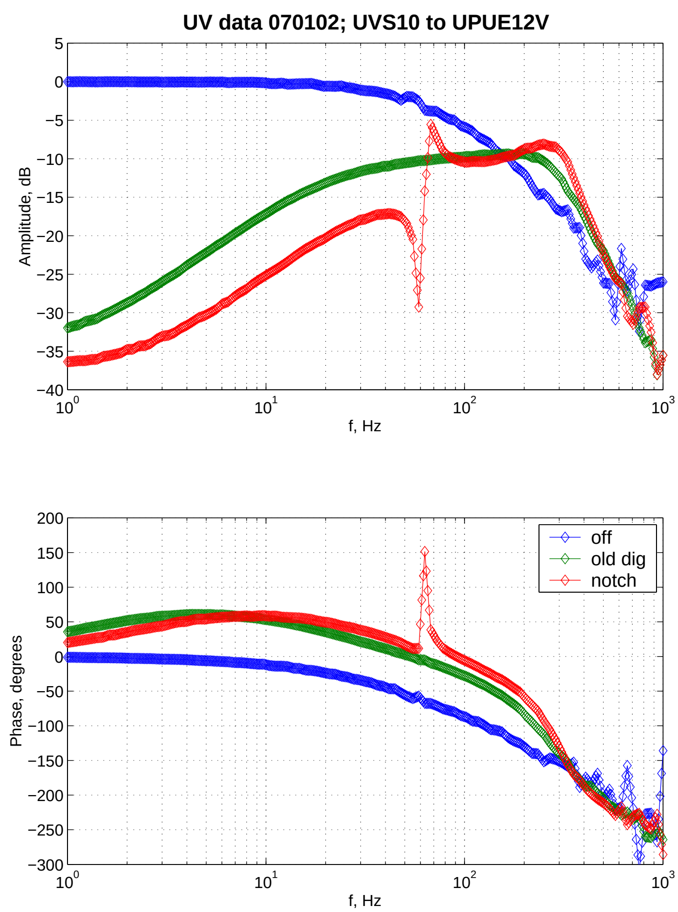
60 Hz Notch Filter I

Basic Idea

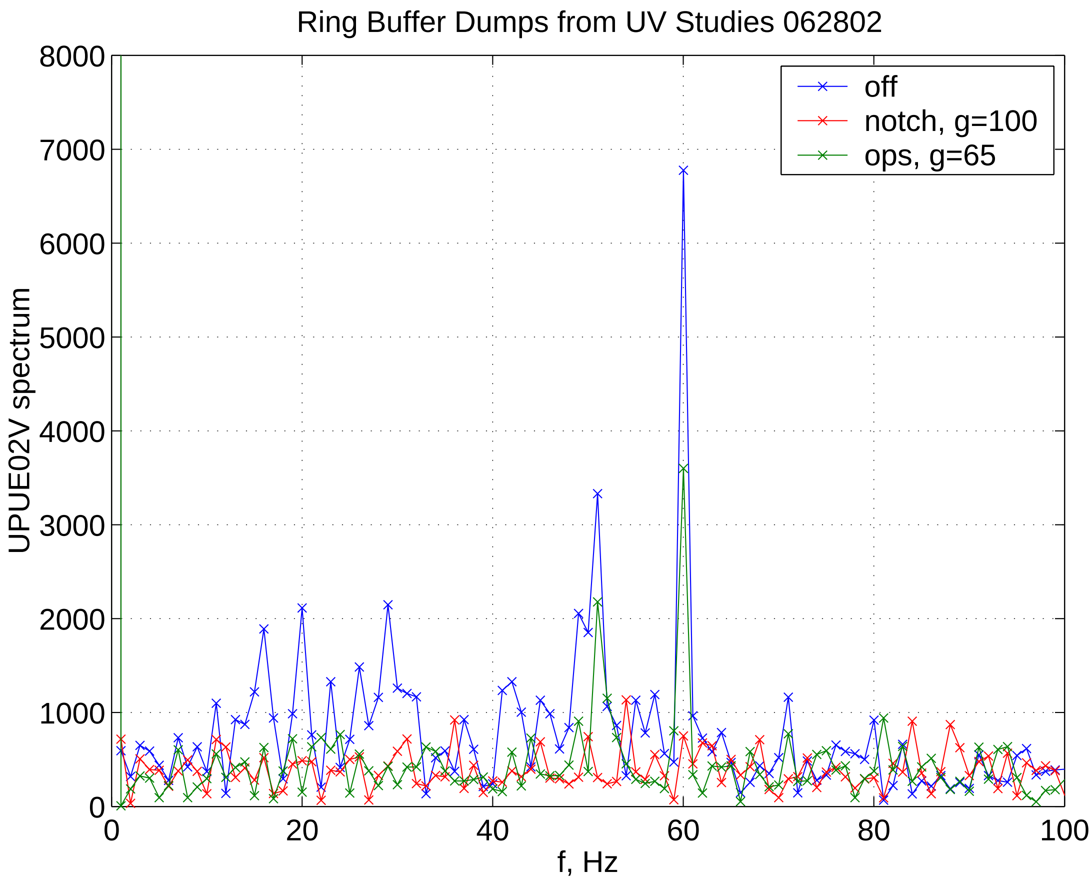


Implementation

- 60 Hz is damped >25 dB
- Regular Ops in VUV ring since July, 2002
- Works in the X-ray as well



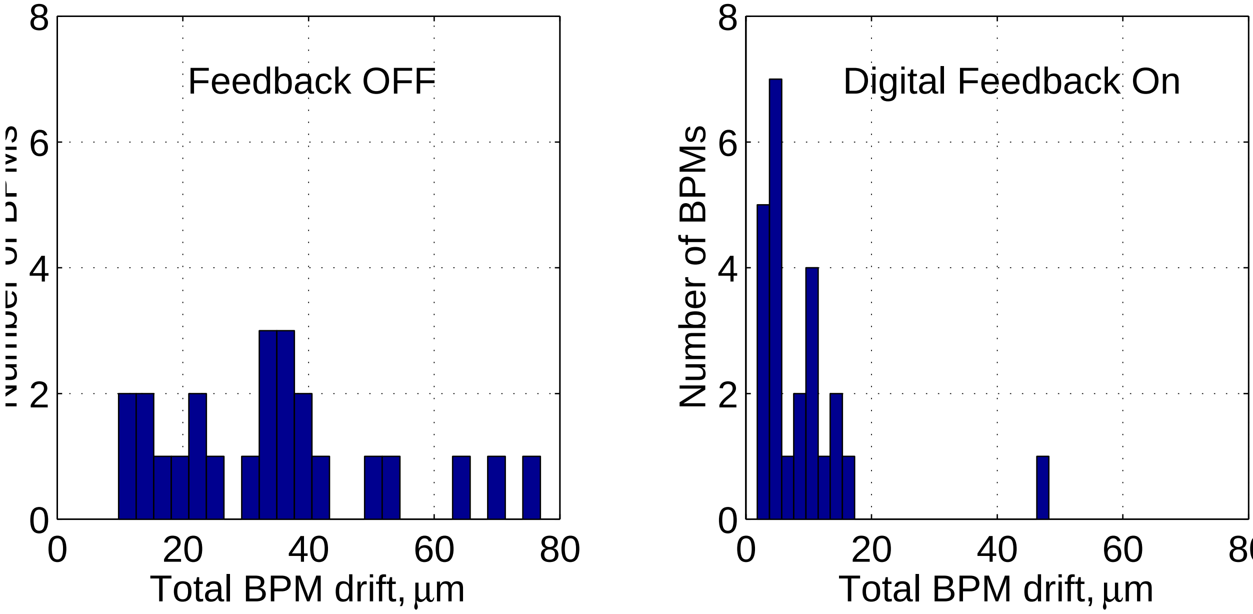
60 Hz Notch Filter II



- Similar low frequency behavior but
- 60 Hz power-line noise is virtually eliminated

Long Term Orbit Drift

Conditions: Standard VUV Ops, 5 hour fill, 830 mA>I>350 mA

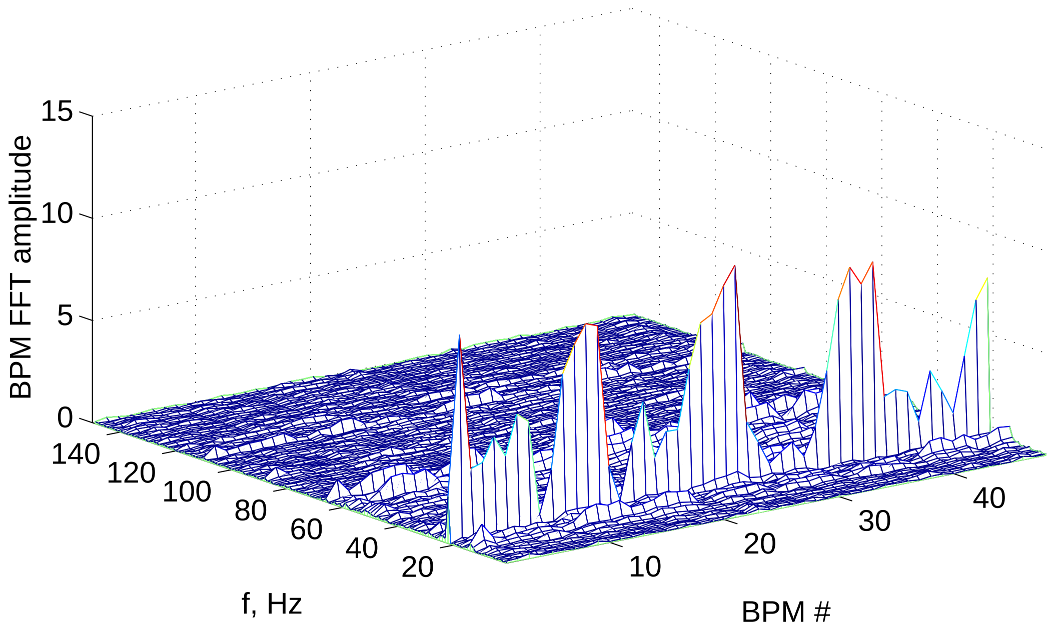


- Average drift reduced from 35 µm to 6 µm (<3% FWHM vertical size)
- Same in horizontal

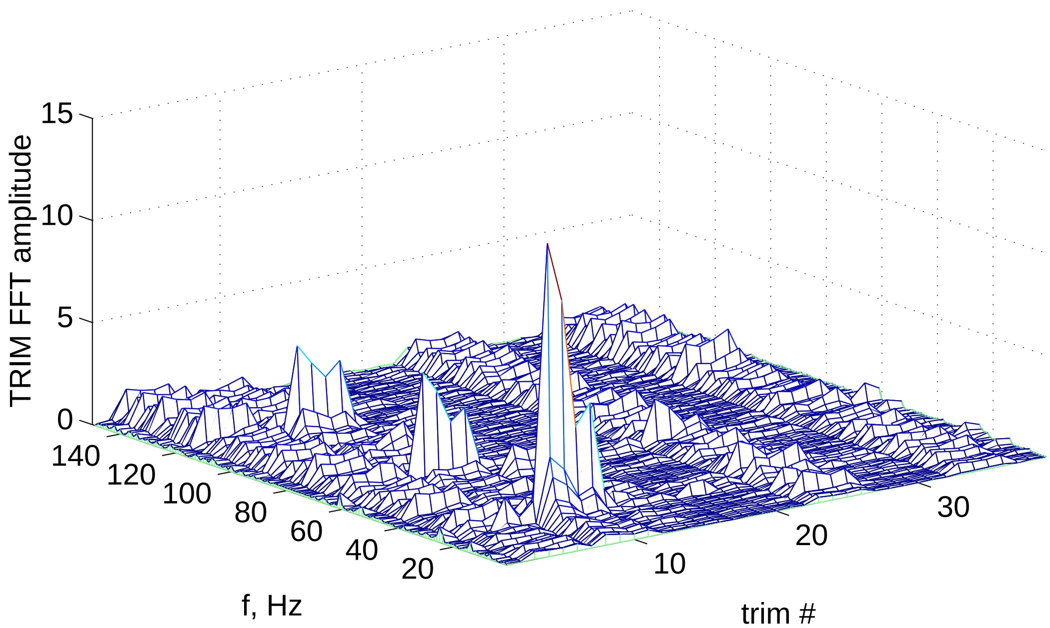
- X-ray ring:
  vertical O.K. (<10% of beam size)
  horizontal - looks O.K. but systematic BPM errors...

Machine Diagnostics

X−ray Ring Buffer Orbit Dump 04/01/01 ~19:15; All Feedbacks Off



X−ray Ring Buffer Trim Dump 04/01/01; Digital Feeback ON



Challenges and Future Work

- How to implement global and local correction together?

  SVD + BPM weights

- How to add photon blade monitors to the system?

  trivial except RM with IDs closed

- Which trims & BPMs to use? Optimal algorithm?

  experience + simulations

- How to account for BPM errors due to mechanical motion?

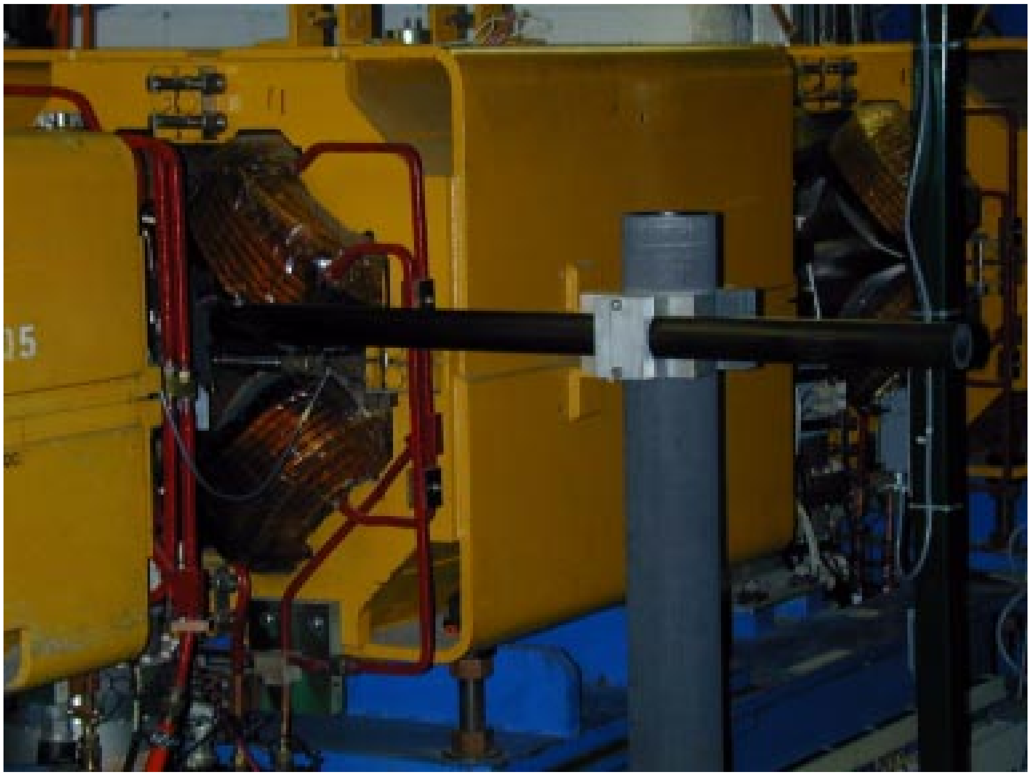
  "monitor the monitors"

- How to handle PS saturation?

  brute force + simulations

BPM Errors due to Beam Pipe Motion I

- "Old digital system" used to give smaller horizontal orbit drift with increased # of eigenvectors
- Users observed the opposite...
- This was traced to the beam pipe motion
- Ceramic stands to measure this motion were built



BPM Errors due to Beam Pipe Motion II

- Observations

- Ultimate Fix

  Real time measurement of BPM motion

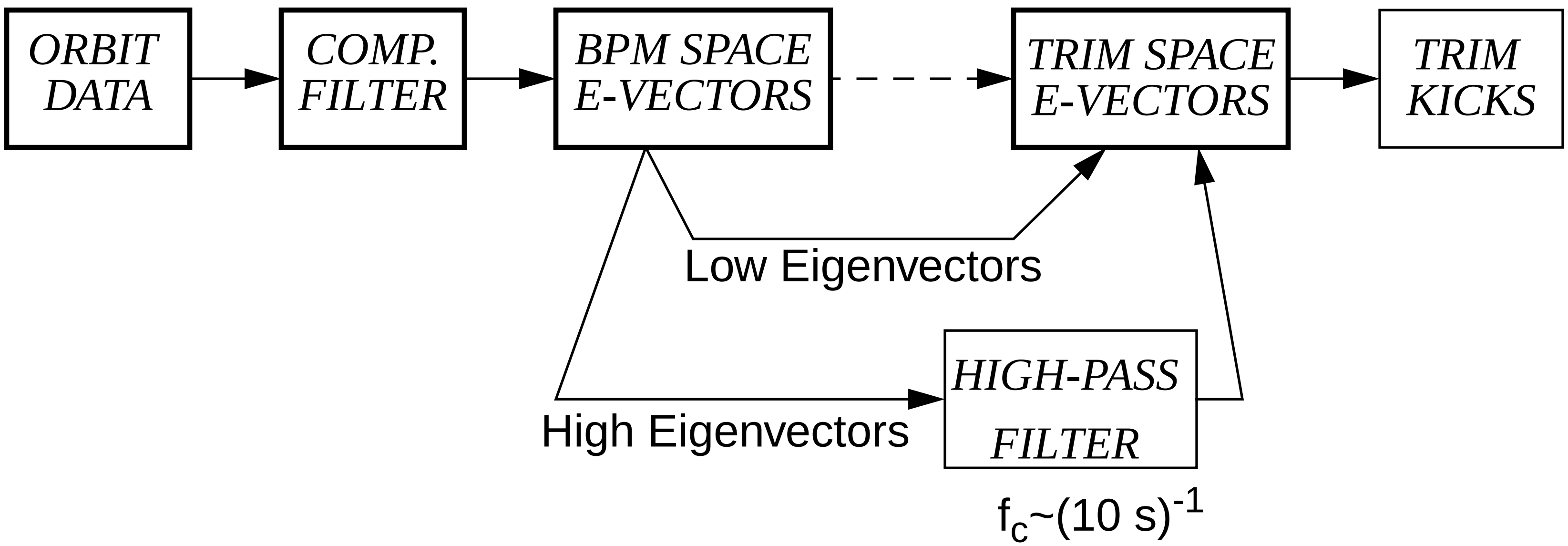
  Account for the error before feedback correction

- Simpler solution

  Use a look-up table based on beam current, beam pipe temperature etc.

BPM Errors due to Beam Pipe Motion III

- Short Term Fix Based on Timescale Separation

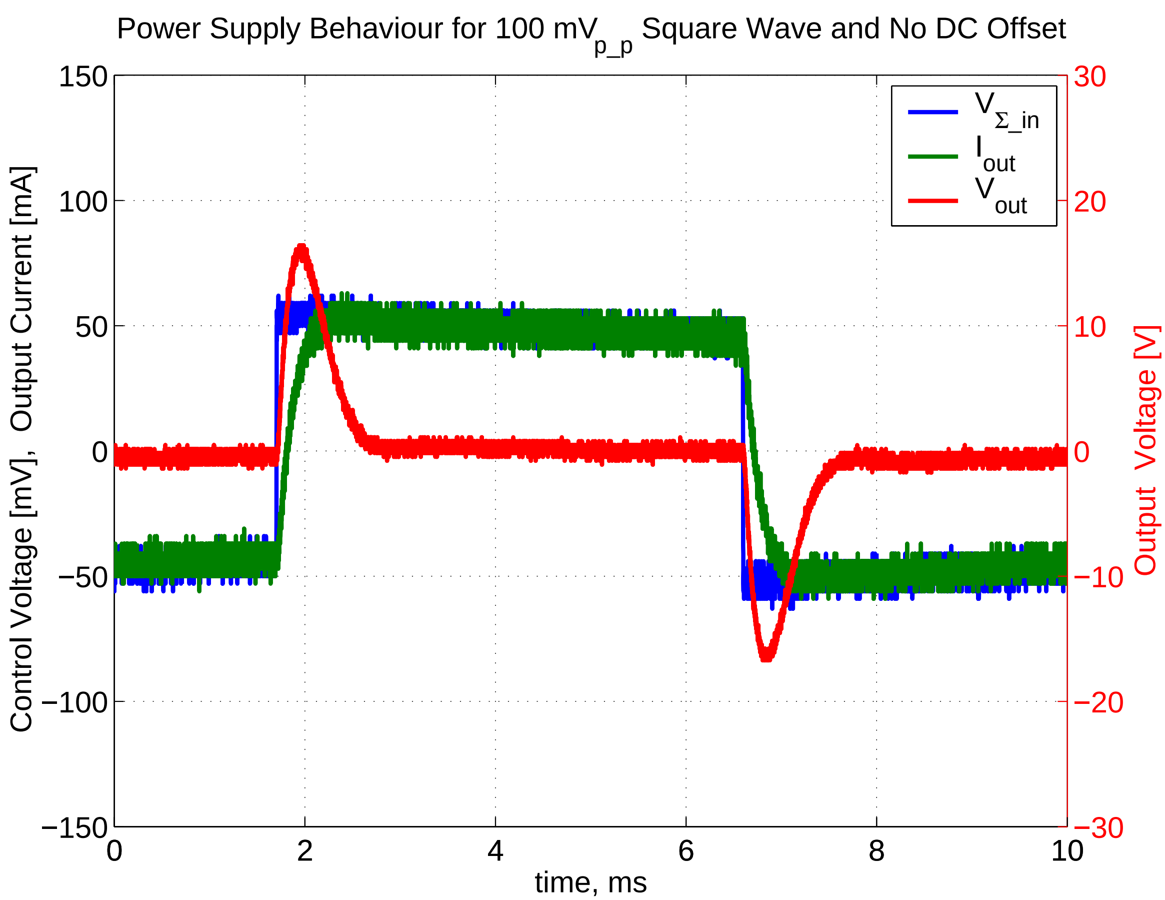


Slow drift -> fewer eigenvectors

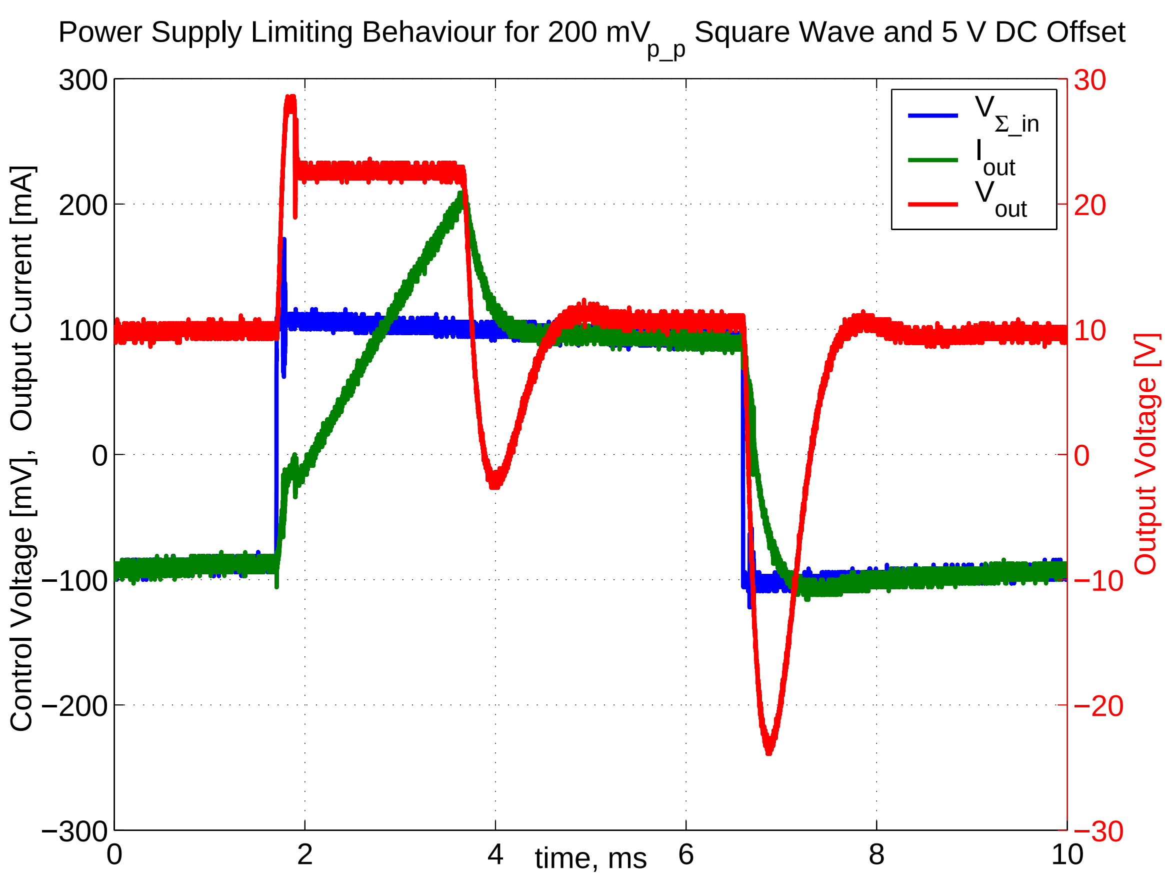
High frequency noise -> more eigenvectors

Trim Power Supply Saturation I

- Trims are inductive for fast feedback (L=20-40 mH, R~1 Ω)
- We use KEPCO BOP-20-10 power supplies
- They are not optimized for inductive loads (voltage limit)
- Spiky output when slew rate or voltage limits reached
- Have to be smart to handle saturation properly
- Problem is for X-ring only (many saturated trims)



Trim Power Supply Saturation II



Summary and Outlook

- We have built a 5 kHz digital orbit feedback system

- Significant improvement over the existing analog system
  - Orbit Noise Correction
  - Slow Drift Reduction
  - Use for Machine Diagnostics
  - Flexibility, Ease of Maintenance, Reliability etc.

- VUV ring status:
  - The system is used in regular operations

- X-ray ring status:
  - Vertical system is used in regular operations
  - Horizontal: issues with corrector saturation and BPM Stability
  - Will be in Operations Soon

- Further development (algorithms, modelling, etc.)