

Studies of Longitudinal Instabilities in BESSY II Booster

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May 28, 2017



Outline

1 Introduction

2 Multibunch Studies

3 Five Bunch Studies

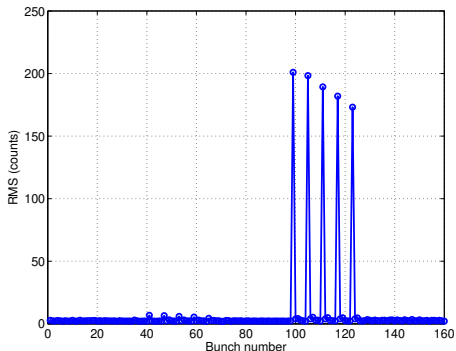


Day Summary

- Hardware setup:
 - ▶ Feedback output drives one vertical stripline via AR 150A220M3;
 - ▶ Input signal is the sum of two vertical pickups;
 - ▶ 30 cm striplines, longitudinal shunt impedance peaks at 250 MHz:
 - ★ For wide bunch spacing used differential kick ($[1 -1]$), effectively upconverting feedback signal to 250 MHz;
 - ★ Multibunch mode — normal kick, zero or low gain for low frequency modes.
- As it turns out, unstable modes are high frequency, very lucky.



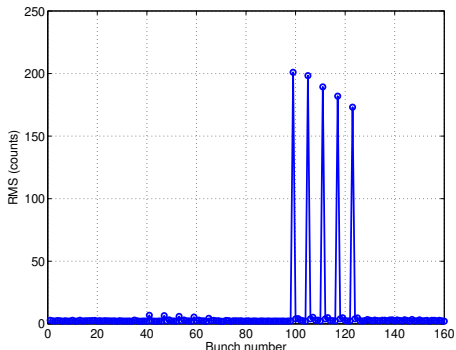
Observing Booster Cycle



- Adjusted timing, feedback works, but takes along time to suppress initial errors;
- 5 bunches, spacing of 6, trigger point not recorded;
- Modal analysis shows oscillations suppressed by 30 ms;
- Bunch spectrogram shows transverse oscillation starting after longitudinal plane quiets down.



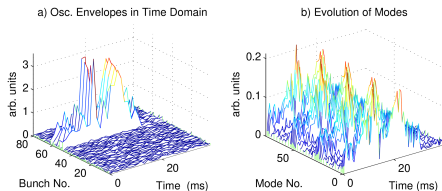
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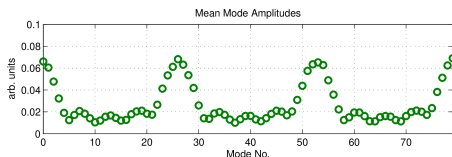
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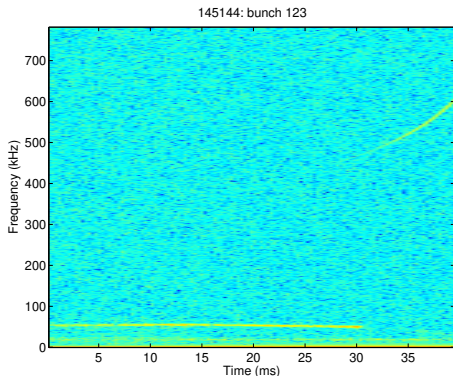
BESSY II Booster: may2817/145144: Io= 3.5912mA, Dsamp= 2, ShiftGain= 7, Nbun= 80,
At v: G1= 0, G2= 1286.6147, Ph1= 0, Ph2= -12.0895, Brkpt= 46745, Calib= 100.



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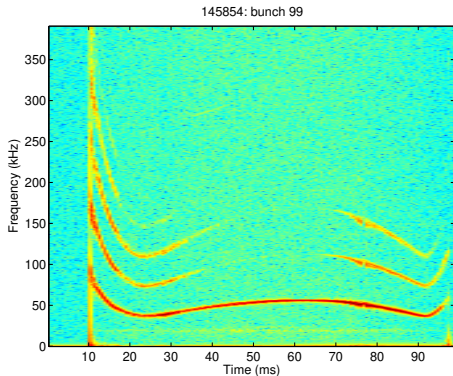
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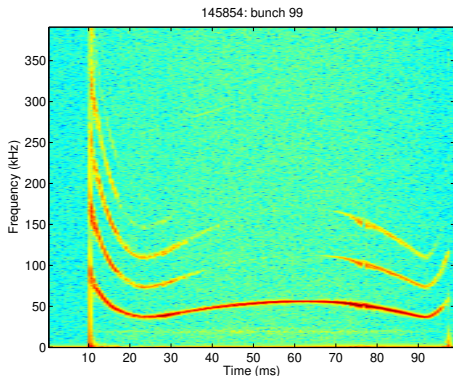
Synchrotron Tune Evolution



- Long record of 100 ms, downsampling of 4;
- Injection around 10 ms;
- Pretty clean tune extraction;
- Can stabilize with two filters, one around 70 kHz, another around 50 kHz, switching 5 ms after injection.



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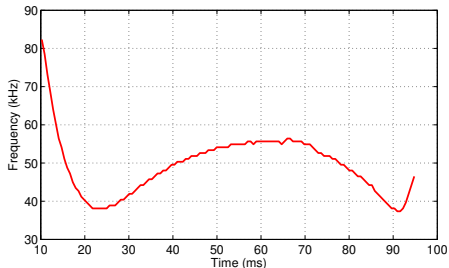
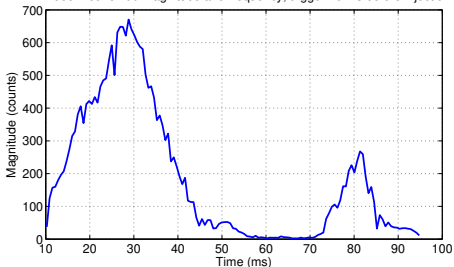


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Synchrotron Tune Evolution

145854: bunch 99 magnitude and frequency, trigger 10 ms before injection

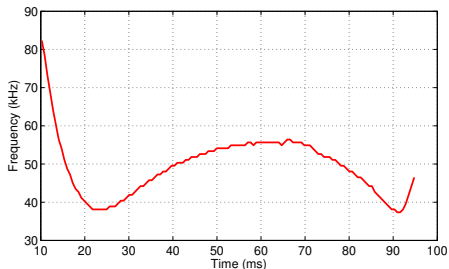
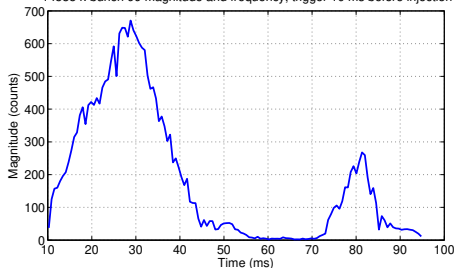


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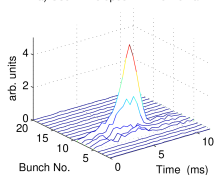


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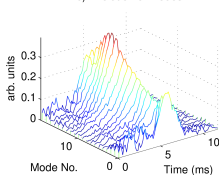


Grow/Damp Measurements Summary

a) Osc. Envelopes in Time Domain

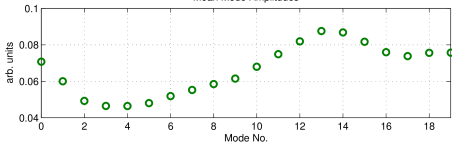


b) Evolution of Modes



BESSY II Booster: may2817/163657: Io= 3.7805mA, Dsamp= 4, ShlfGain= 4, Nibun= 20,
At v: G1= 0, G2= 33.2843, Ph1= 0, Ph2= 120.7733, Brkpt= 4634, Calib= 100.

Mean Mode Amplitudes

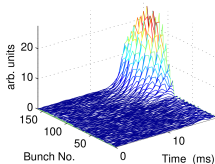


- Five bunch mode studies at different spacings;
- Multibunch studies (spacing of 1);
- Spent some time trying to characterize modal frequency dependence;
- Will start discussion from multibunch results, since these have highest frequency resolution.

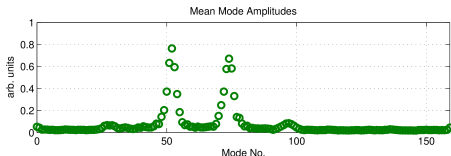
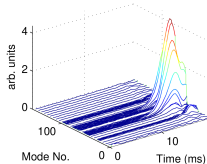


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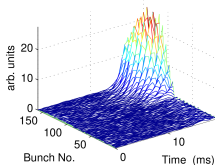


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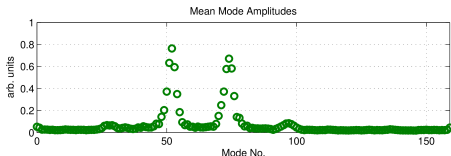
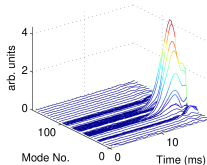


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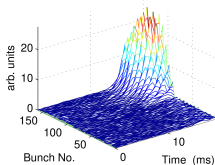


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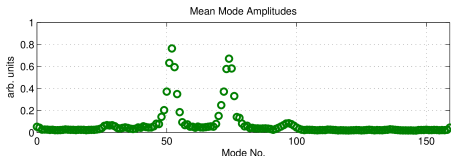
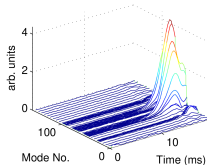


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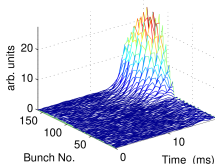
2 Multibunch Studies

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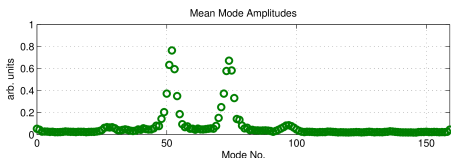
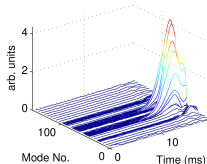


A Single Grow/Damp

a) Osc. Envelopes in Time Domain



b) Evolution of Modes

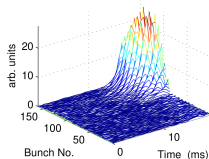


- Two bands of modes centering at 52 and 75;
- Around 162 and 234 MHz respectively (plus an integer multiple of RF);
- Can fit growth rates and frequencies;
- Reasonable fit, moderate growth times on the order of $50T_s$.

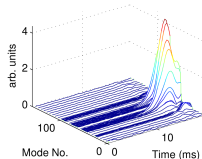


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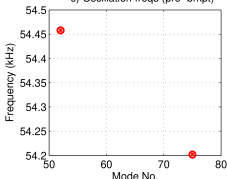
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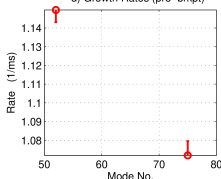
b) Evolution of Modes



c) Oscillation freqs (pre-brkpt)



d) Growth Rates (pre-brkpt)



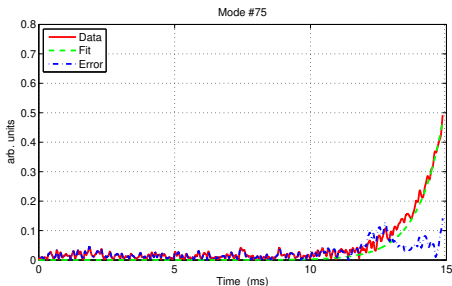
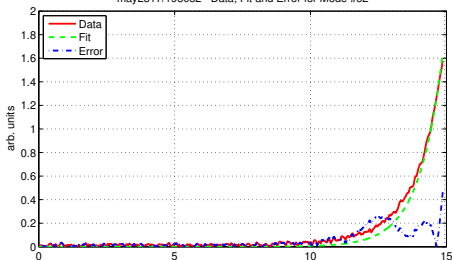
BESSY II Booster: may2817/193032: Io= 3.7068mA, Dsamp= 4, ShifGain= 5, Nibun= 160,
At v: G1= 32.0259, G2= 0, Ph1= 10.4779, Ph2= 0, Brkpt= 11657, Callib= 100.

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A Single Grow/Damp

may2817/193032 Data, Fit and Error for Mode #52

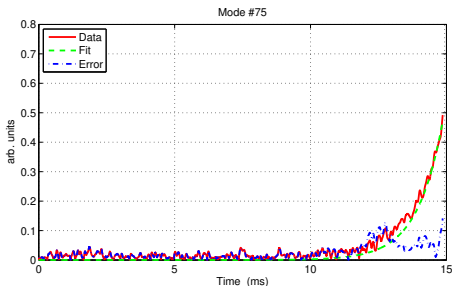
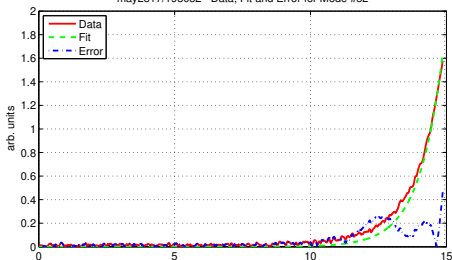


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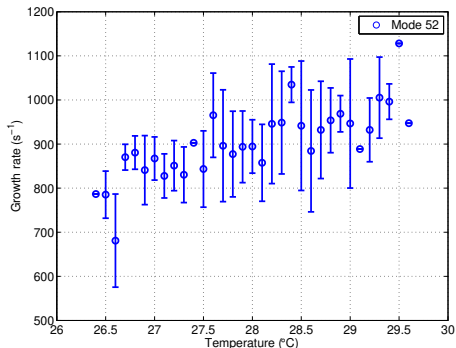
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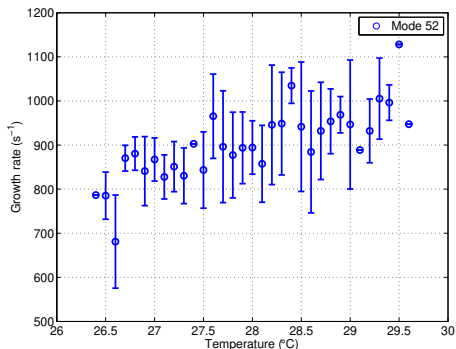
Cavity Temperature Transition



- Two measurements:
 - ▶ Turned off RF, started running with warming cavity;
 - ▶ Ran RF in CW mode, then ran booster with cooling cavity.
- Possibly some dependence for mode 52?
- A lot of scatter for mode 75.



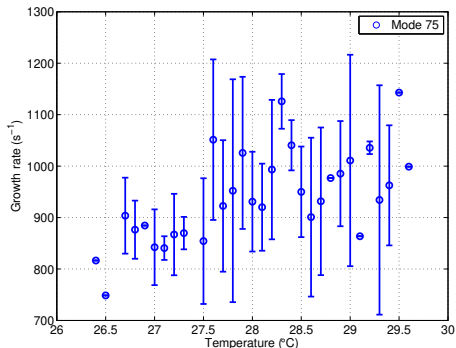
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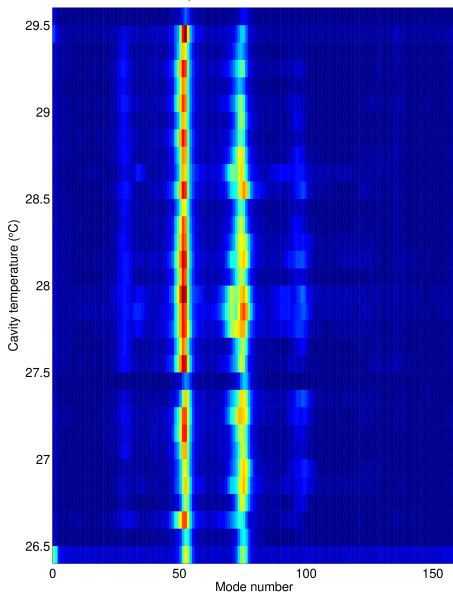


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All Modes vs. Temperature

Mean mode amplitudes, maximum over measurements

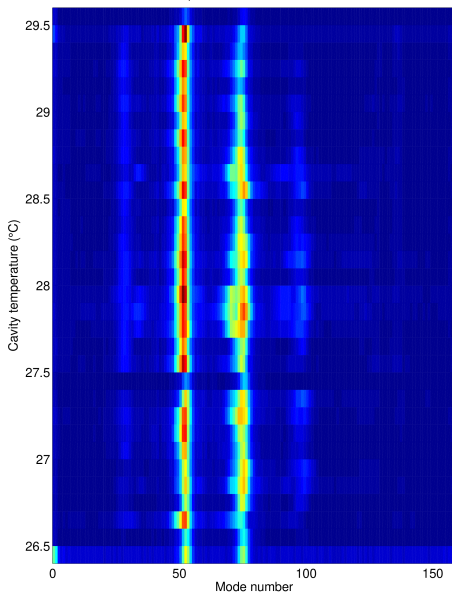


- Making sure no modes were missed in the temperature scan;
- Average mode amplitudes, maximum over measurements at one T_C ;
- Peak mode amplitudes, maximum over measurements.



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Mean mode amplitudes, maximum over measurements

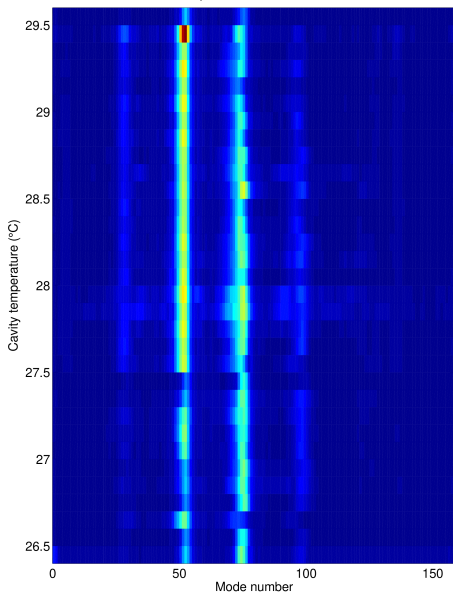


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Mode Aliasing Table

Bunch spacing	h_{eff}	Mode 1	Mode 2
1	160	52	75
4	40	12	35
5	32	20	11
8	20	12	15
10	16	4	11

- Spacing of 5 and 10 nearly couples 52 to -75 and vice versa;
- Theory says these patterns should have better stability;
- Only integer divisors of 160 were investigated.



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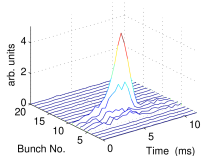
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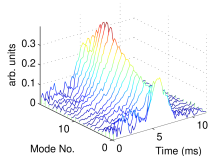


A Single Grow/Damp

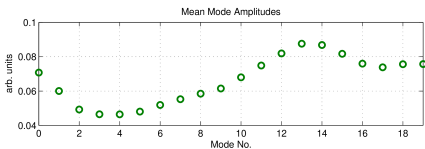
a) Osc. Envelopes in Time Domain



b) Evolution of Modes



BESSY II Booster: may2817/163657: Io= 3.7805mA, Dsamp= 4, ShifGain= 4, Nbun= 20,
At v: G1= 0, G2= 33.2843, Ph1= 0, Ph2= 120.7733, Brkpt= 4634, Calib= 100.

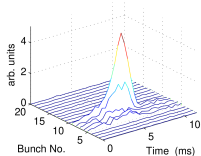


- Spacing of 8, expect 12 and 15;
- Roughly right modes, too short a train to resolve;
- Fit mode 13, probably both eigenvalues together;
- Clean fits.

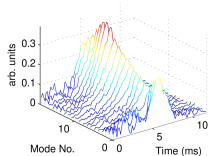


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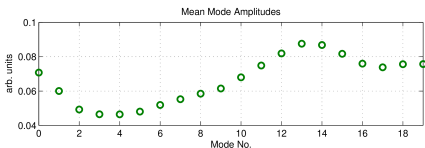
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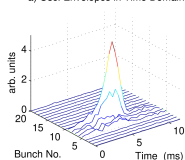


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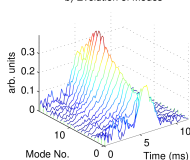


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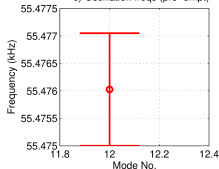
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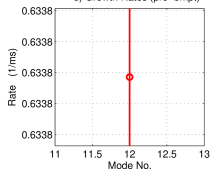
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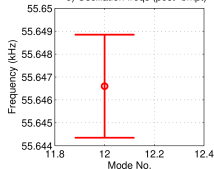
c) Oscillation freqs (pre-brkpt)



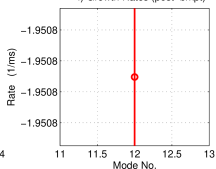
d) Growth Rates (pre-brkpt)



e) Oscillation freqs (post-brkpt)



f) Growth Rates (post-brkpt)

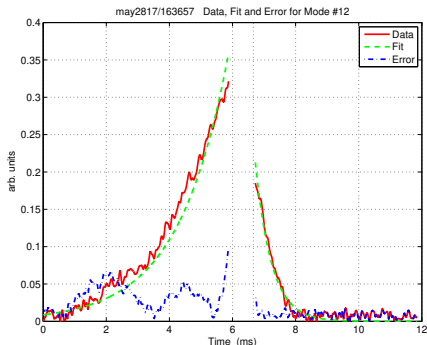


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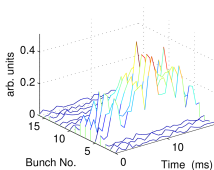


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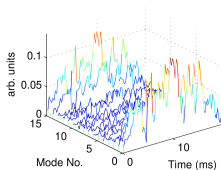


Bunch Spacing Study

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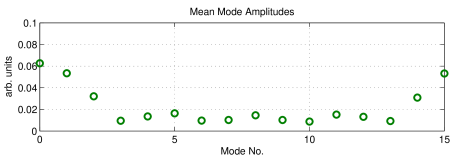


b) Evolution of Modes



BESSY II Booster:may2817/165947: Io= 3.5815mA, Dsamp= 4, ShifGain= 5, Nbun= 16,

At v: G1= 0, G2= 62.3966, Ph1= 0, Ph2= 125.8304, Brkpt= 14393, Calib= 100.

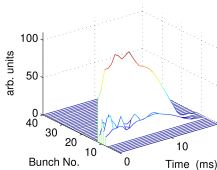


- Spacing of 10, stable;
- Spacing of 4, didn't get a growth rate, mode 35 (expected);
- Spacings of 5 and 8 compared.

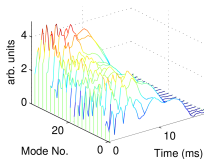


Bunch Spacing Study

a) Osc. Envelopes in Time Domain



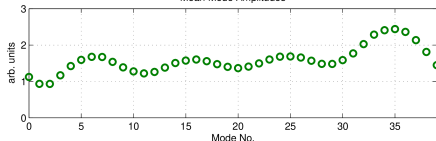
b) Evolution of Modes



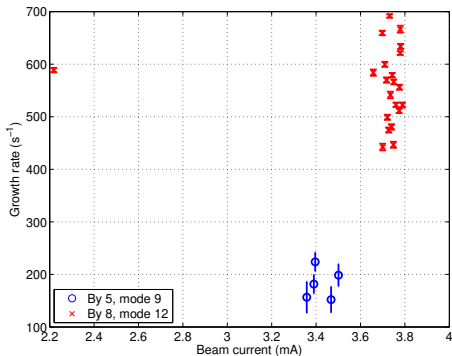
BESSY II Booster:may2817/173041: Io= 3.2241mA, Dsamp= 4, ShifGain= 5, Nbun= 40,
At v: G1= 0, G2= 45.785, Ph1= 0, Ph2= -83.9532, Brkpt= 9313, Calib= 100.

- Spacing of 10, stable;
- Spacing of 4, didn't get a growth rate, mode 35 (expected);
- Spacings of 5 and 8 compared.

Mean Mode Amplitudes



Bunch Spacing Study



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- Spacings of 5 and 8 compared.



Summary

- **Relatively successful demo, given the weak kicker;**
- Identified the longitudinal modes, checked different bunch spacings;
- No strong sensitivity to cavity temperature;
- Some transverse motion might be happening with the beam longitudinally stable;
- Based on the synchrotron frequency variation along the ramp, two filters should be able to handle the full range.



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