Microwave Instability Studies in NSLS-II

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U.S. DEPARTMENT OF ENERGY | Office of Science

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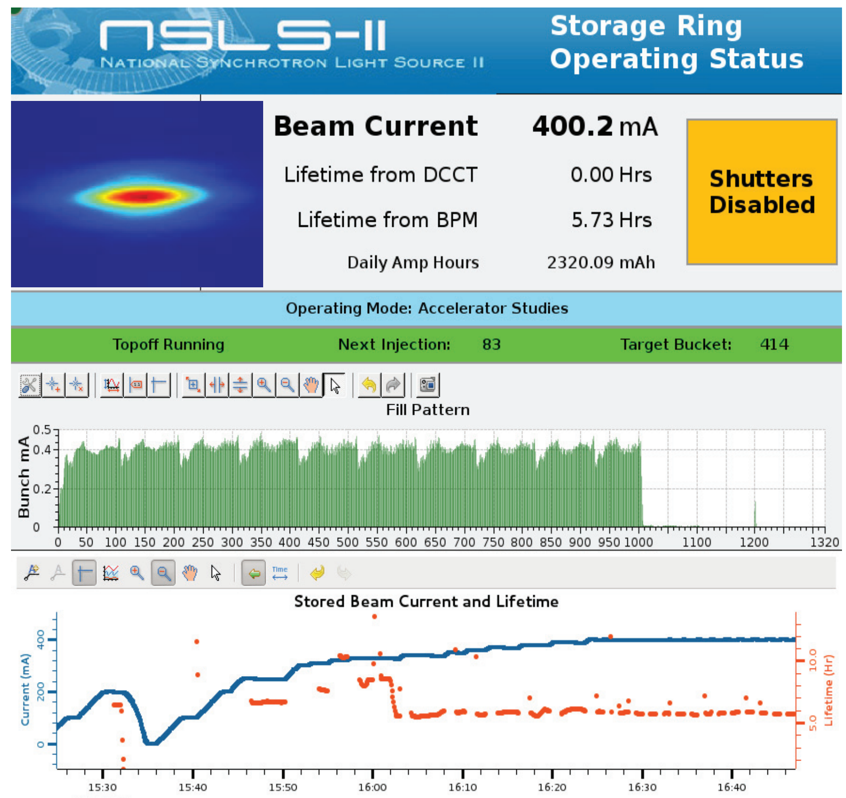
Outlook

- Average Current of 400mA Achieved (500mA goal)
- Longitudinal Instability Thresholds Measurements
- Numerical Simulations of the Instability Thresholds for NSLS-II and APS.
- Summary

NSLS-II Beam Intensity Increasing

02 Jul. 2014	25 mA with CESR-B SC RF cavity
11 Jul. 2014	First time at 50mA
14 Jul. 2014	Shutdown for ID and FE installation
03 Oct. 2104	Start of ID commissioning
23 Oct. 2014	First light on beamline flag!
11 Feb. 2015	**Beamline operations begins at 25 mA**
25 Feb. 2015	50 mA with IVU's magnet gap closed
11 Mar. 2015	First time at 100 mA
15 Apr. 2015	First time at 150 mA
17 Apr. 2015	**Beamline operations begins at 50 mA**
23 Apr. 2015	First time at 200 mA
Jul. 2015	**Beamline operations begins at 150 mA**
28 Jul. 2015	First time at 300 mA
Oct. 2015	**Start operation with Top Off at 150 mA**
04 Jan. 2016	Start operation with 2^{nd} RF cavity
29 Jan. 2016	**Beamline operations begins at 175 mA**

16 Feb. 2016	First time at 350 mA
17 Feb. 2016	**Beamline operations begins at 200 mA**
14 Apr. 2016	**Beamline operations begins at 250 mA**
18 Apr. 2016	First time at 400 mA

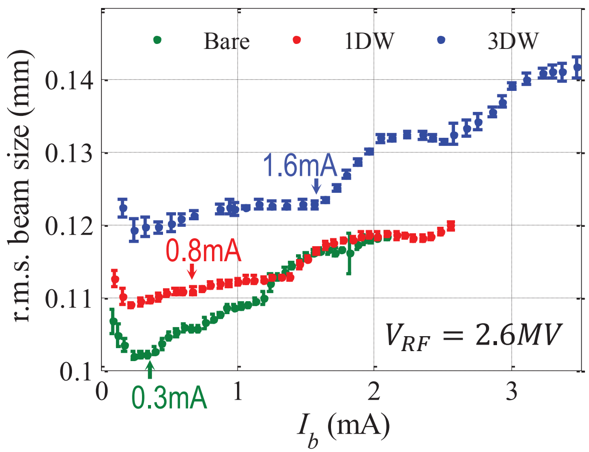


NSLS-II Parameters for the Collective Effects Characterization

Energy,	$E_0(GeV)$	3
Revolution period,	$T_0(\mu s)$	2.6
Momentum compaction,	α	3.7 x 10^{-4}
Energy loss,	$U(keV)$	287 (BM) 674 (BM + 3DW's)
RF voltage,	$V(MV)$	3.6
Synchrotron tune,	ν_s	9.48 x 10^{-3} (BM + 3DW's)
Damping time,	$\tau_x, \tau_s(ms)$	54, 27 (w/o DWs) 23, 11.5 (with 3DWs)
Energy spread,	$\sigma_{\varepsilon 0}$	5 x 10^{-4} (BM) 8.8 x 10^{-4} (BM + 3DW's)
Bunch duration,	$\sigma_s(mm)$	2.4 (w/o DWs) 4 (with 3DWs) Ignoring bunch lengthening

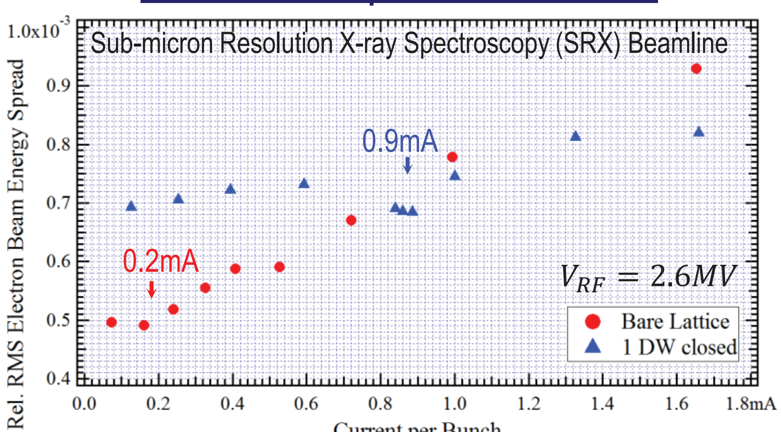
Longitudinal Instability Thresholds Measurements

Synchrotron Light Monitor



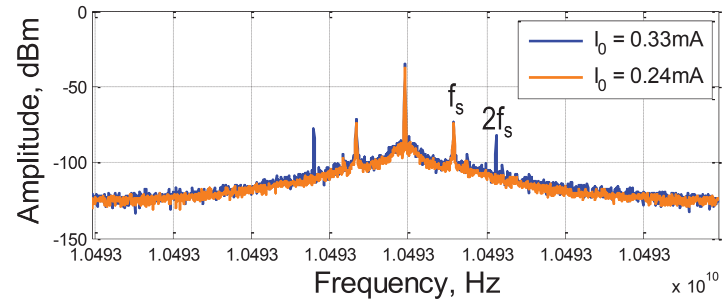
Horizontal beam size change vs single bunch current for different lattices, Bare Lattice, 1 DW and 3 DW gap closed

Radiation Spectrum of IVU

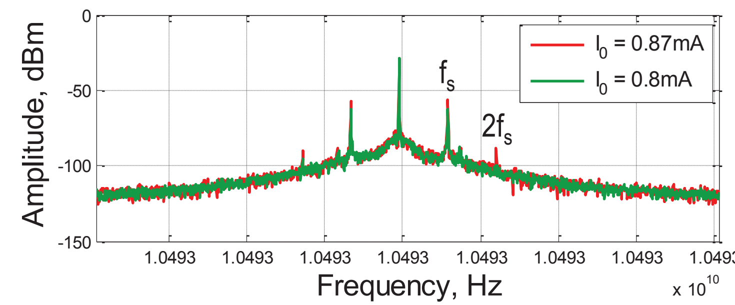


The energy spread measurements based on the IVU spectrum

Beam Spectra



Bare Lattice (All ID's Gap Open)



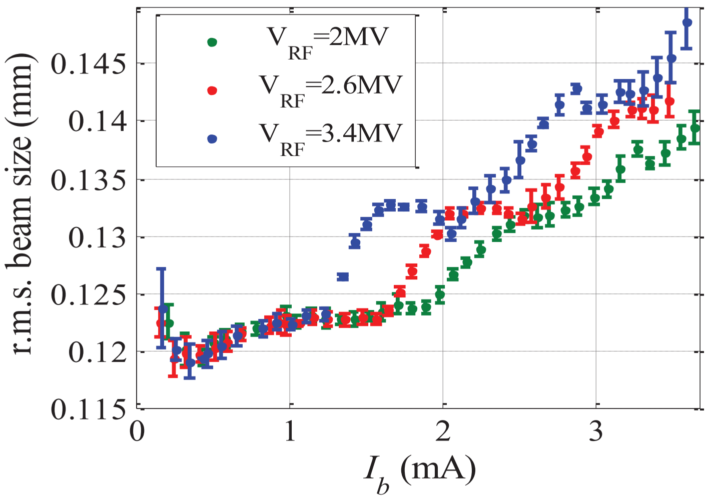
One DW magnet gap closed

- First Instability Threshold $I_{th1} \sim \sigma_\varepsilon^3$
- Appearance of high f_s-harmonics ($2f_s, 3f_s, \ldots$)
- There is NO frequency shift of high-harmonics

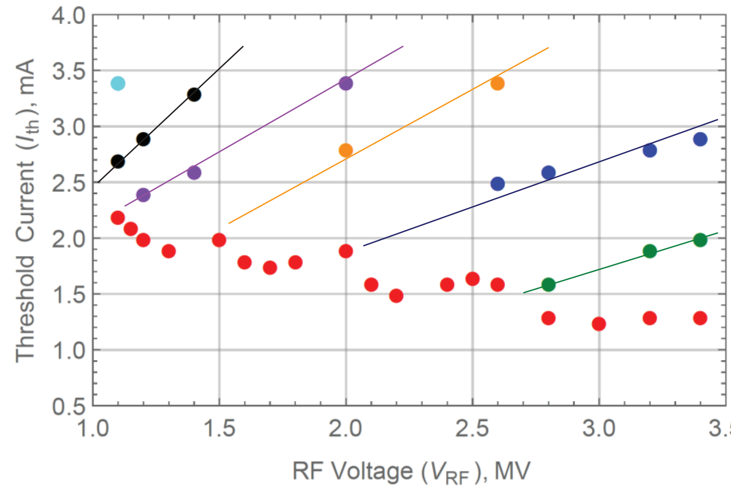
* r.m.s beam size measurements for Bare Lattice presented by W. Cheng at IPAC16, "Experimental Study of Single Bunch Instabilities at NSLS-II Storage Ring"

Horizontal Beam Size Change vs. RF Voltage

3DWs Magnet Gap Closed (Operation Lattice)

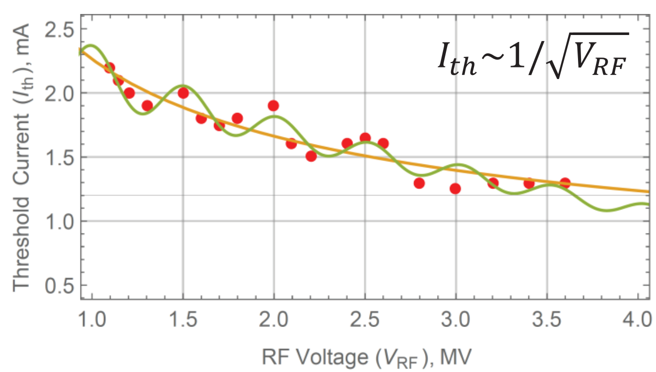


Synchrotron Light Monitor Camera Measurements



Measured Longitudinal Instability Thresholds vs. RF Voltage

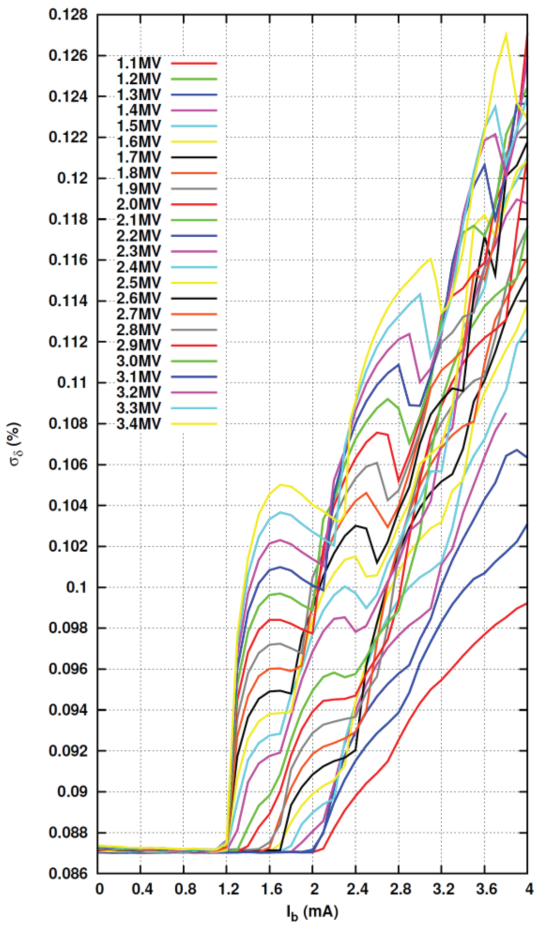
- The microwave instability threshold current at $V_{RF} = 3.6MV$ is $I_{th1} > 1mA$



$$I_{th} \sim \frac{1}{\sqrt{V_{RF}}\left(1 - \frac{A\cos(\alpha V_{RF})}{\sqrt{V_{RF}}V_{RF}}\right)}$$

Measurements vs. Numerical Simulations

SPACE Code Numerical Simulations

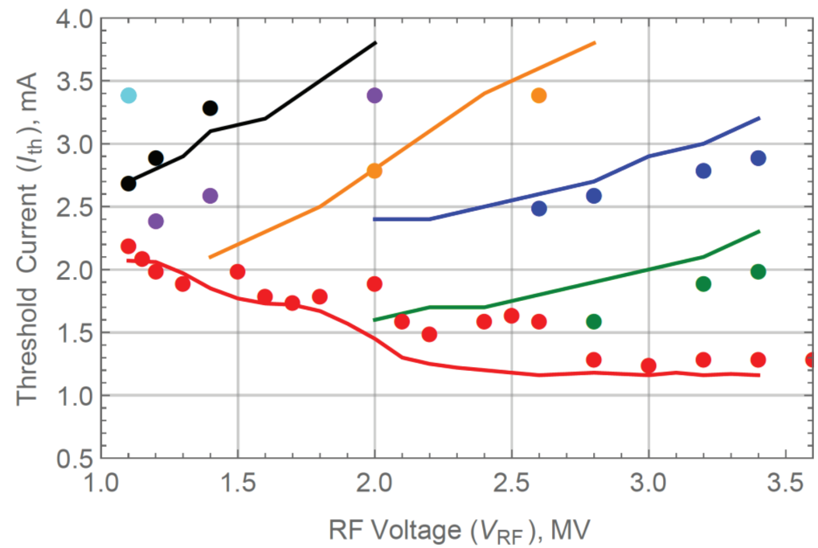


Numerically Simulated Energy Spread vs. Single Bunch Current for Different RF Voltages

Longitudinal Broad-Band Impedance Model

f_r, GHz	$R_{sh,\|\|}$, $k\Omega$	Q
20	8	4
58	4.3	3.5

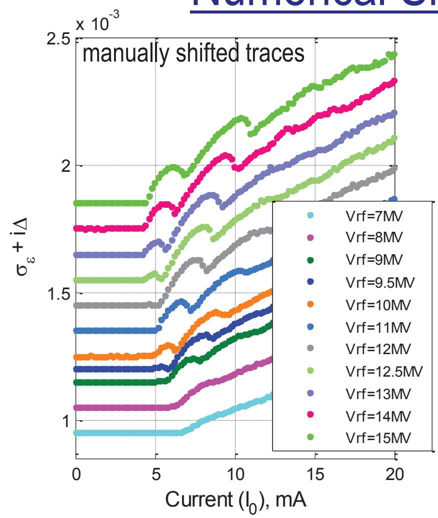
- High frequency contribution (>30GHz) is missed in a 3mm impedance budget
- $Z_{\|\|,tot}$ modelled by two BBRs (Fitting measured data)
- $Z_{\|\|,tot}$ is updated including high-frequency contribution.

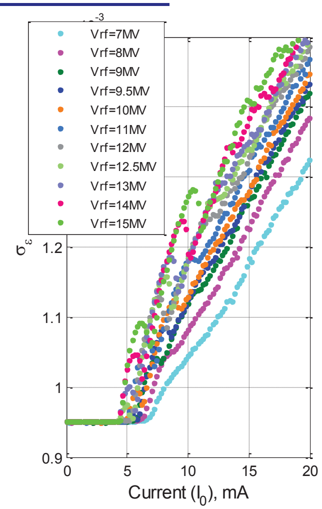


Results Comparison. Measurements vs. Numerical Simulations
Dots - Measured results. **Lines** – Numerical Simulations

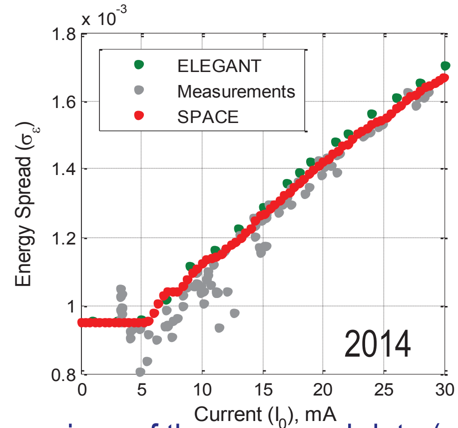
APS Storage Ring

Numerical Simulations

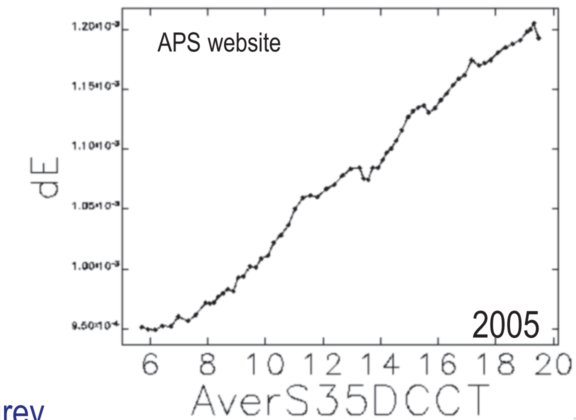




Energy spread vs. single bunch current for different RF voltages

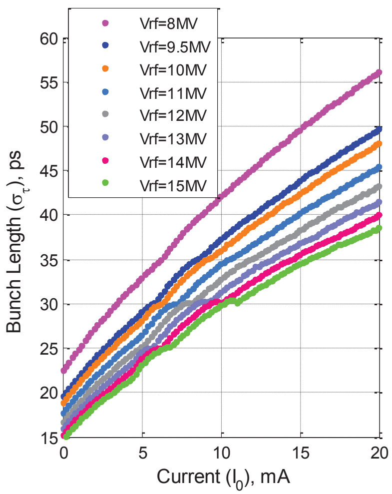


Comparison of the measured data (grey dots) with numerical results, ELEGANT (green dots) and SPACE (blue dots).

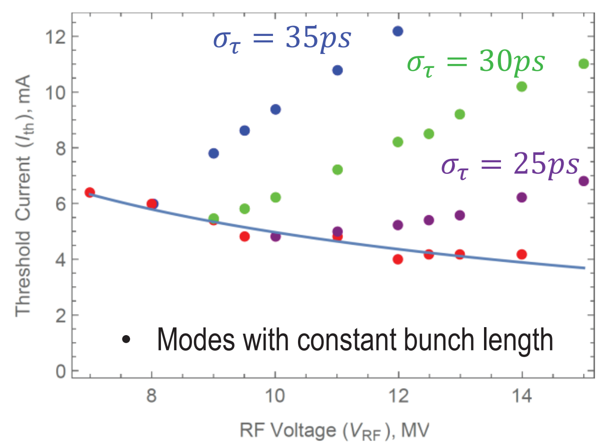


Energy spread vs single bunch current measurements at RF voltage 7MV

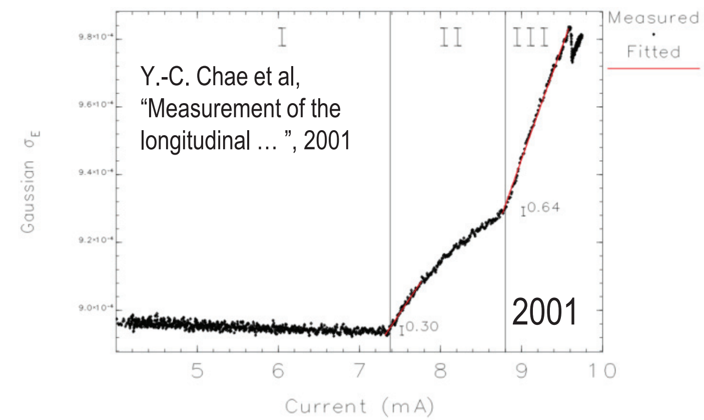
Courtesy by R. Lindberg



Bunch length vs. single bunch current at different RF voltages



The simulated data for the longitudinal instability thresholds vs the RF voltage



Energy spread vs single bunch current measurements at RF voltage 9.4MV

Summary

- Multiple longitudinal instability thresholds observed at NSLS-II
- Preliminary simulations using the simple BBR model show approximate agreement with the measured data.
- The measured microwave instability threshold is proportional to the cube of the energy spread $I_{th1} \sim \sigma_\varepsilon^3$ as predicted by the theory.
- The first instability threshold approximately follows $I_{th1} \sim 1/\sqrt{V_{RF}}$ dependence.
- Higher order thresholds confirmed by simulations for NSLS-II and APS.
- Further investigations continue

Acknowledgments

- **BNL/NSLS-II**

  B. Bacha, G. Bassi, G. Wang, T. Shaftan, V. Smaluk, W. Cheng, S. Kramer. L.-H. Yu, D. Padrazo, O. Singh, E. Zitvogel, A. Derbenev, R. Smith, R. Reiner, O. Chubar, Y.-C. Karen

- **ANL/APS**

  R. Lindberg, B. Stillwell