Overview of Operational Fast Orbit Feedback Systems around the World

Workshop on Next-Generation
Fast Orbit Feedback Systems
for Storage Rings

APS/CNM/EMC Users Meeting
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Overview

- Machine Main Parameters
- Correctors and correction BW
- Achieving and measuring orbit stability
- Operational Experience

Overview of Light Sources - Main Parameters

	year	E [GeV]	I [mA]	C [m]	ϵ_x [nm rad]	ϵ_y [pm rad]	K [%]	β_x [m]	β_y [m]	σ_x [μm]	σ_y [μm]
SLS	2001	2.4	400	288	5	35	0.7	1.4	0.9	84	5.6
CLS	2005	2.9	500	171	20.5	92	0.45	9.5	2.6	441	15.5
ASP	2006	3	200	216	6.98	63	0.9	9	2.45	251	12.4
SLS*	2006	2.4	400	288	5.5	5.5	0.1	1.4	0.9	84	2.1
Soleil	2007	2.75	500	354	3.7	37	1	4	1.77	122	8.1
Diamond	2007	3	300	562	2.7	27	1	4.6	1.5	111	6.4
SSRF	2008	3.5	300	432	3.9	39	1	3.6	2.5	118	9.9
PETRA III	2009	6	100	2304	1	10	1	20	5	141	7.1
ALBA	2010	3	400	269	4.3	40	0.9	2	1.3	93	7.2
ESRF-U	2011	6	300	844	4	10	0.25	35.2	2.52	375	5.0
NSLS-II	2015	3	500	792	0.9	8	0.89	1.5	0.8	37	2.5

Table - Summary of main parameters (Light sources completed recently or under construction – G. Rehm 2008)

- Most light sources horizontal Emittance → 5 nm rad +/- 2 nm rad
- Petra III, NSLS-II → Emittance ~ 1 nm rad
- SLS* → smallest vertical beam size in ID center (2.1 micron), by changed optics & coupling
- Spear III → operational since 2004; TPS → operational in 2014
- Orbit stability goals → < 10 % beam size

SOFB & FOFB Systems – Correctors/ Correction Bandwidth & present status

SR Facility	FB type (users operation)	Sets of correctors	Bandwidth
ALBA*	Fast	Strong	DC - 130 Hz
BESSY II *	Fast	Strong	DC - 40 Hz
DIAMOND	Fast	Strong	DC - 130 Hz
ELETTRA	Fast	Strong	DC - 150 Hz
ESRF-U*	Fast	Strong	DC - 150 Hz
SLS	Fast	Strong	DC - 100 Hz
SPEAR3	Fast	Strong	DC - 100 Hz
ALS	Slow + Fast	Strong (+ Fast as a subset of slow ones)	DC - 60 Hz
APS	Slow + Fast	Strong (+ Fast as a subset of slow ones)	DC - 100 Hz
ESRF	**Slow + Fast**	**Strong + Fast**	**DC - 150 Hz**
NSLS II*	**Slow + Fast**	**Strong + Fast**	**DC - 500 Hz**
PETRA III*	**Slow + Fast or Fast**	**Strong + Fast**	**Dead-band or DC - 500 Hz**
SOLEIL	**Slow + Fast**	**Strong + Fast**	**DC - 250 Hz**
SSRF*	**Slow + Fast**	**Strong + Fast**	**DC - 100 Hz**

* FOFB not operational as of 2009

- All Correctors Chambers → Fast
- ESRF → upgrade in progress for all subsystems

- All Correctors available for SOFB
- Only a subset or a separate set of correctors for FOFB
- Forces to use slow + fast systems
- Introduces dead-band issues
- Implementation evolving towards overlap BW feedback systems
- Petra III FOFB in operation
- SSRF/ TPS FOFB in test/ commissioning

Table - Fast Orbit Feedback System Status as of 2009 – N. Hubert

Achieving & Measuring Beam Stability - G. Rehm (SRI 2012)

Ring/Plane	FOFB	ϵ [nm rad]	β [m]	η [mm]	σ_E[%]	σ_e [µm]	σ'_e [µrad
ALBA/H	No	4.5	2.06	82.6	0.11	132	47.4
ASLS/H	No	10.3	9.05	100	0.1	321	33.7
ESRF/H	Yes	4	0.35	31	0.11	72	100
DLS/H	Yes	2.7	4.65	52	0.096	123	24.1
Soleil/H	Yes	4.4	4.6	165	0.1	221	30.5
ALBA/V	No	0.023	1.22	0	0.11	5.2	4.3
ASLS/V	No	0.12	2.42	0.7	0.11	17	7.06
ESRF/V	Yes	0.007	2.96	0	0.11	4.6	1.53
DLS/V	Yes	0.027	1.53	0	0.096	6.4	4.2
Soleil/V	Yes	0.033	2.36	0	0.1	8.7	4.6

Table - Electron beam parameters at the center of straight

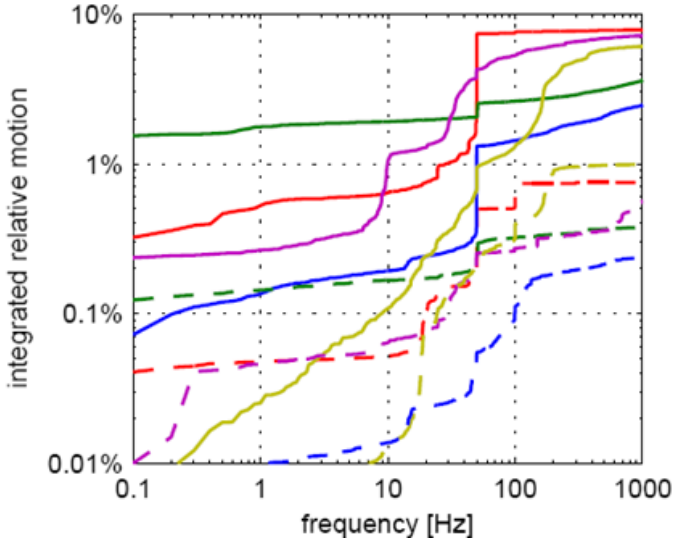


Fig - Integrated motion relative to the respective vertical (solid) and horizontal (dashed) beam sizes –

- ALBA - green
- ASLS - red
- ESRF - purple
- DLS - yellow
- Soleil - blue

- ALBA & ASLS – data without Fast Orbit Feedback
- Up to 10 Hz – orbit stable to < 2% level of beam size
- 50 Hz & harmonics (power line) contribution high
- Meets 10 % stability requirement up to 1000 Hz

Petra III FOFB – 1 of 3

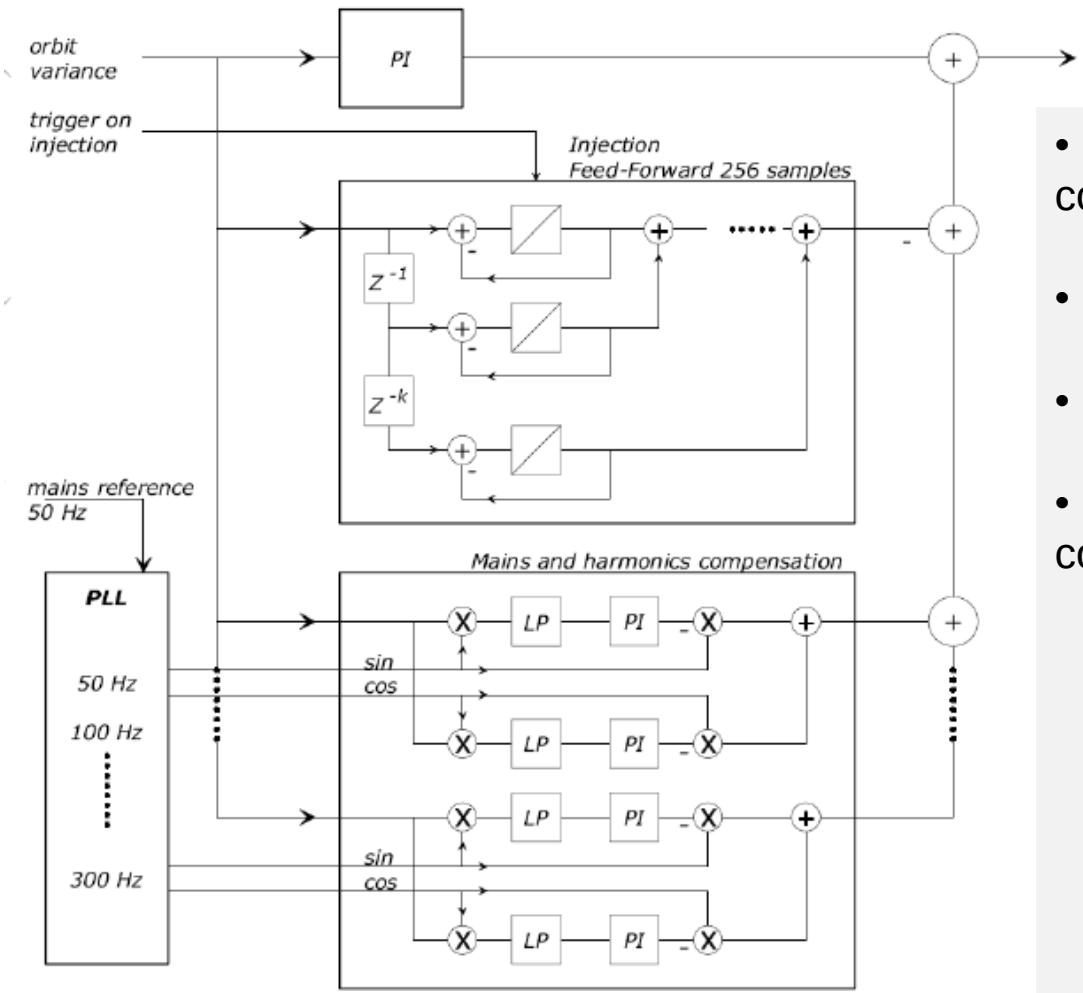


Figure 1: Signal flow for one of the 80 processing channels.

J. Klute et al; DIPAC 2011

- FOFB → 226 bpm x 40 air core corrector in each plane
- 24 distributed processing racks
- Has a STAR topology
- 80 processing channels, each consists of three sections –
  - o PID loop for normal orbit correction
  - o Feedforward to compensate for injection bump mismatch with 256 integrators in each channel
  - o Compensating orbit influence due to main frequency and its harmonics

Petra III FOFB – 2 of 3

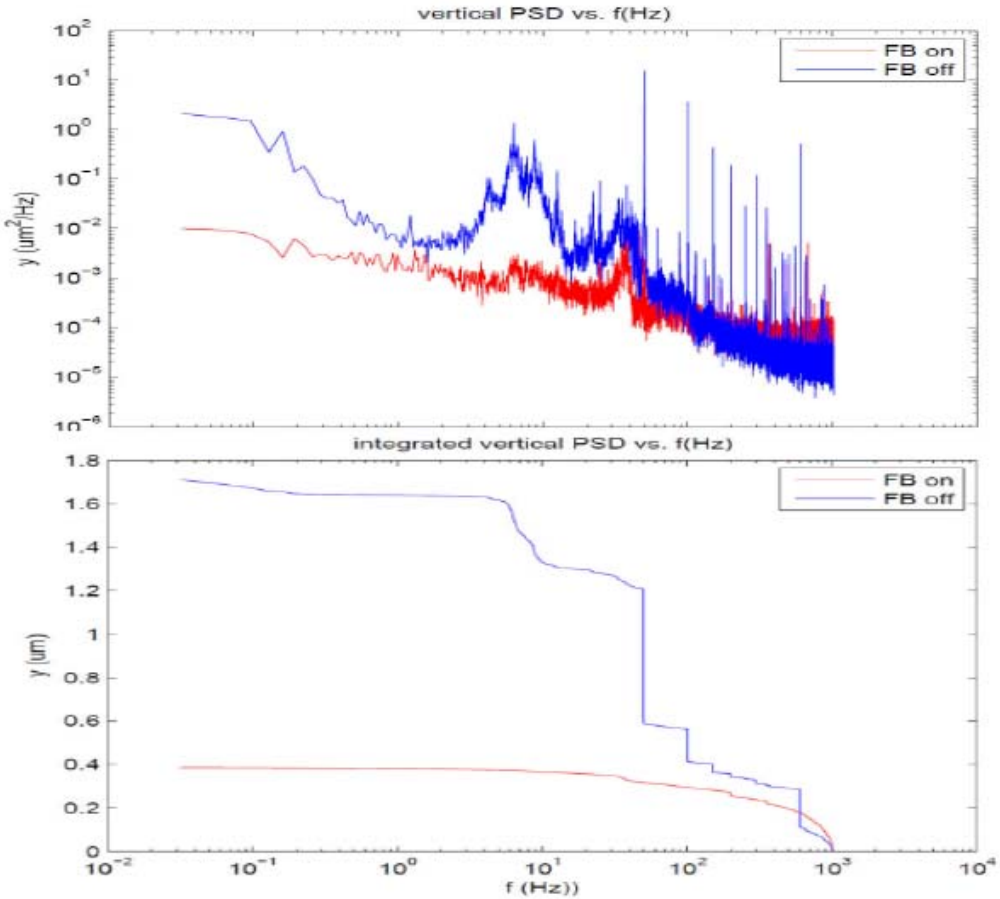


Figure 5: On top the vertical PSD, and below the SQRT of its integral, taken when FOFB is off and on.

- Corrector system → - 3 db @ 715 Hz
- FOFB damps orbit at low frequency quite well; but shows slight increase (overshoot) in orbit above 200 Hz;
- Vertical stability achieved
  → 0.4 micron (< 10 % beamsize)
- Fast corrector strength → 45 micro-radian; Sufficient for 50 hrs of operation run.
- Fast corrector DC can be released to slower (stronger) corrector when needed

Petra III FOFB – 3 of 3

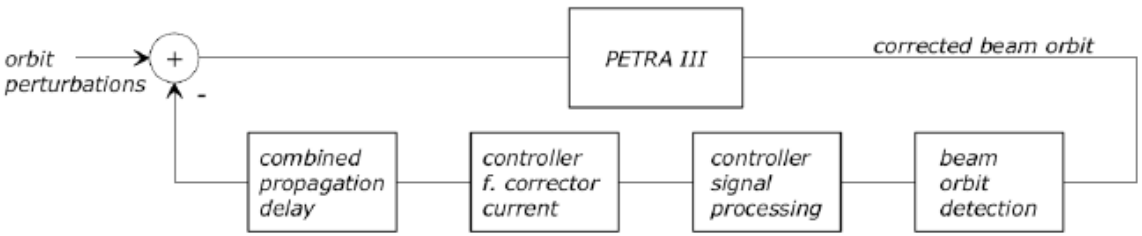


Figure 2: Model for closed loop response calculation.

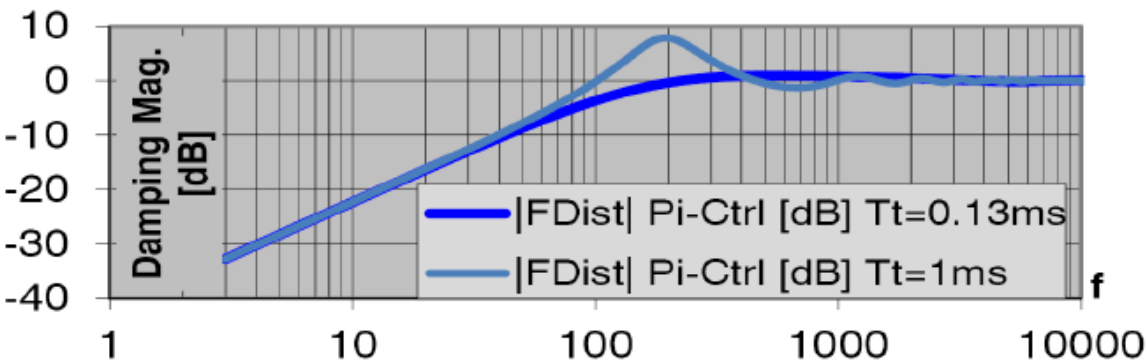


Figure 3: Analytic closed loop response, calculated for two different reaction times due to signal propagation.

- Model consists of four feedback blocks
- Typical signal propagation delay in feedback system is 0.13 msec
- Closed loop responses are calculated for two delays –
  - 0.13 ms delay → smooth closed loop response
  - 1.0 ms delay → close loop response shows overshoot with peak at 200 Hz.

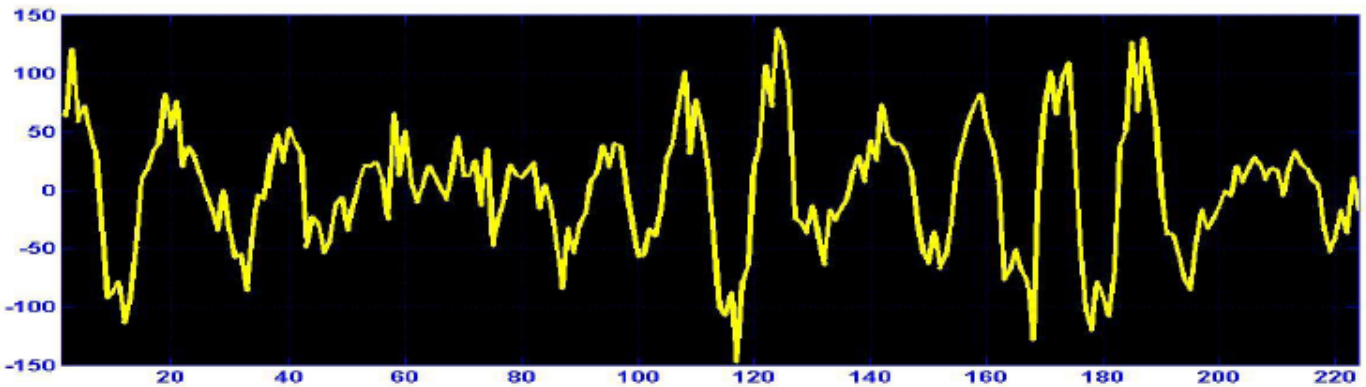
ESRF FOFB System – 1 of 5

Global reliability of the BPM hardware (incl. RF connections) in 2012 :

MTBF : infinite !

Non-availability : zero !

In 2012 (since restart in May) , all 224 BPMs , were all the time , in good working order



we can easily live with a few stations less ,

BUT it is the <u>transition time</u> of excluding a faulty station that can be delicate and painful (as happened last week)

Kees Scheidt – ESRF May, 2013
5 Slides

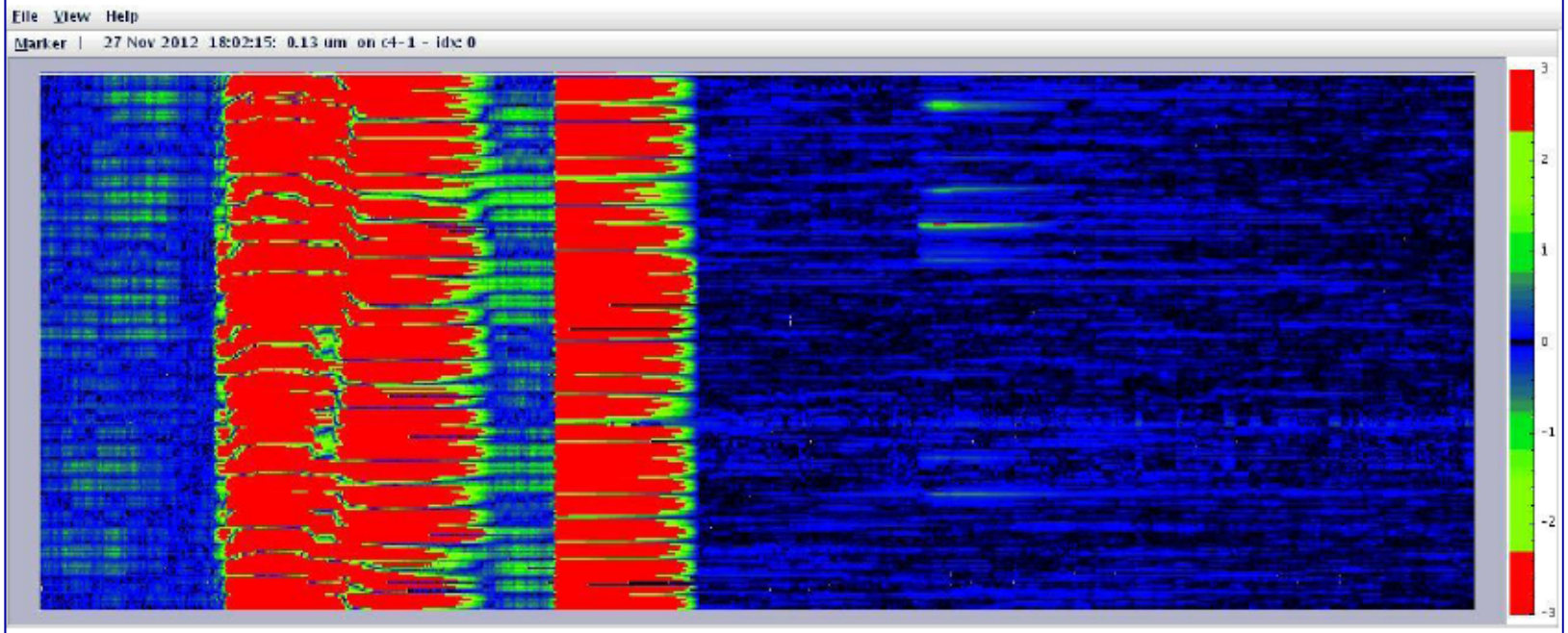
ESRF FOFB System – 2 of 5

The BPM system is an essential component in the Closed-Orbit-Stabilization system :

Now :	**until May 2013 :**
the **Slow-Fast**-Orbit-Stabilization uses :	the **Fast**-Orbit Stabilization was limited :
224 Libera BPMs	32 Hor-Fast-BPMs 32 Vert-Fast-BPMs
96 AC-DC Steerers	32 AC Hor-Steerers 16 AC Vert-Steerers

ESRF FOFB System – 3 of 5

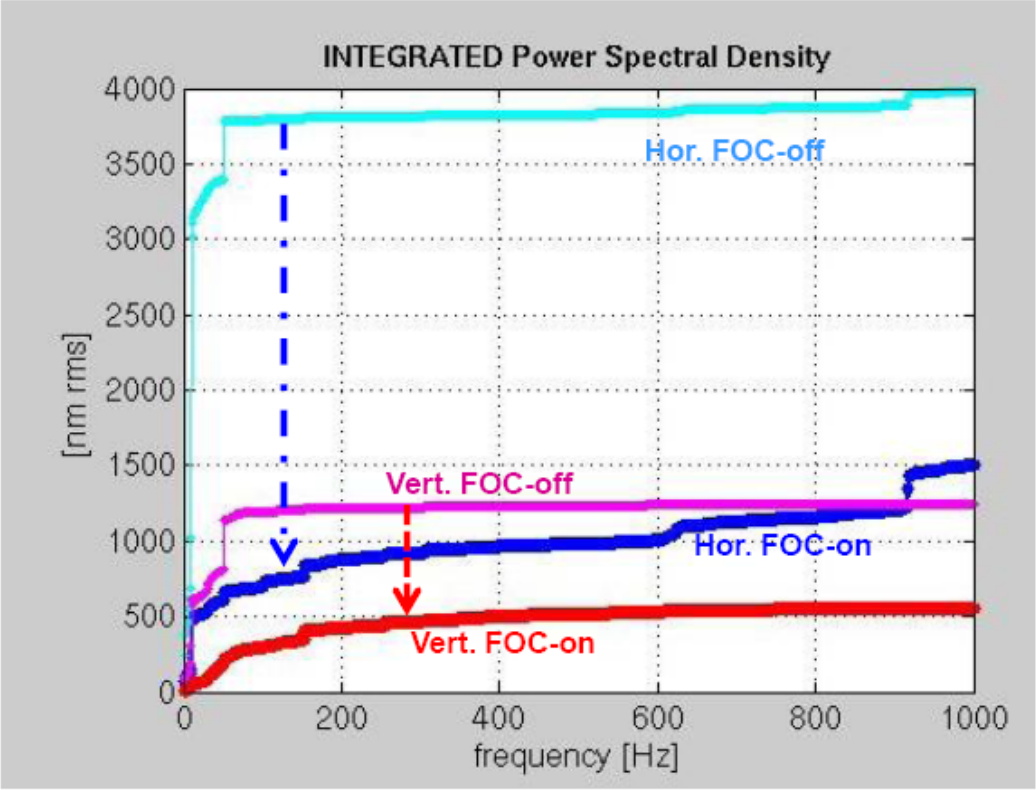
The huge benefit in beam stability thanks to FOC is the damping of ID-gap manipulations



- Left: effect of the gap opening and closing during an injection procedure without FOC
- Right: effect of the gap opening and closing during an injection procedure with the FOC active …

damping of AC motions

Vertical motion integrated from 0 to 1000Hz = 500nm (vert.)



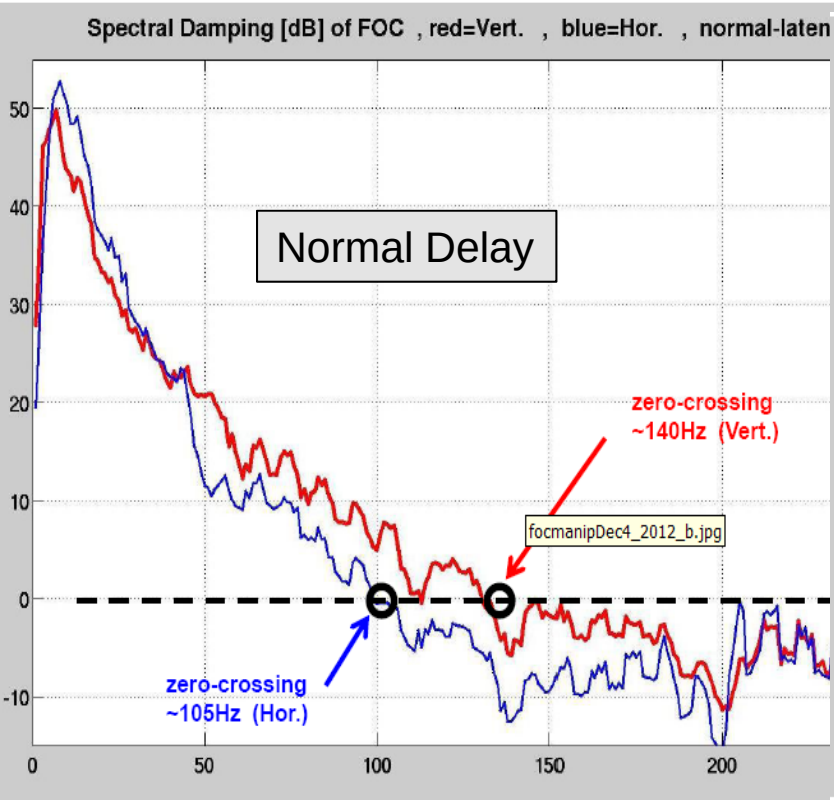
sub-micron vertical rms residual motion

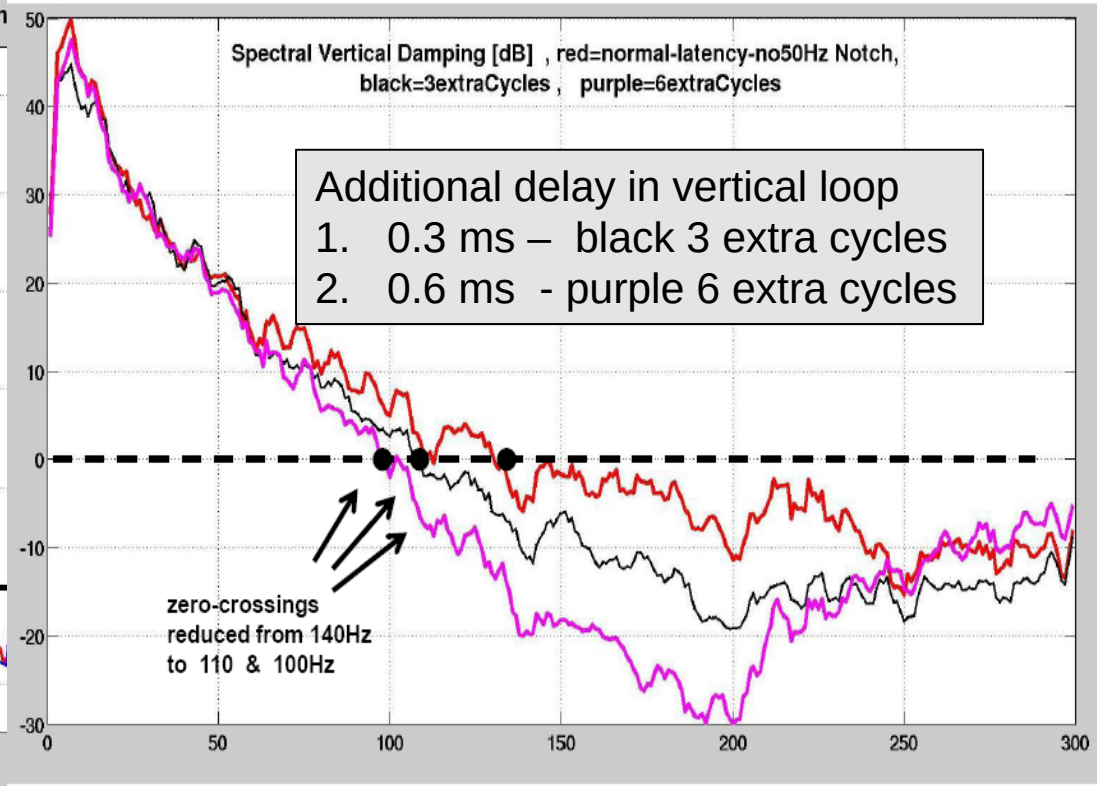
→ vertical motion < 10% vertical beamsize

$\varepsilon xOFF=1.3\ 10^{-12}$	$\varepsilon zOFF=3.5\ 10^{-13}$
$\varepsilon xON=1.3\ 10^{-13}$	$\varepsilon zON=1.3\ 10^{-14}$
$\varepsilon xbeam=4\ 10^{-9}$	$\varepsilon zbeam=4\ 10^{-12}$

ESRF FOFB System – 5 of 5

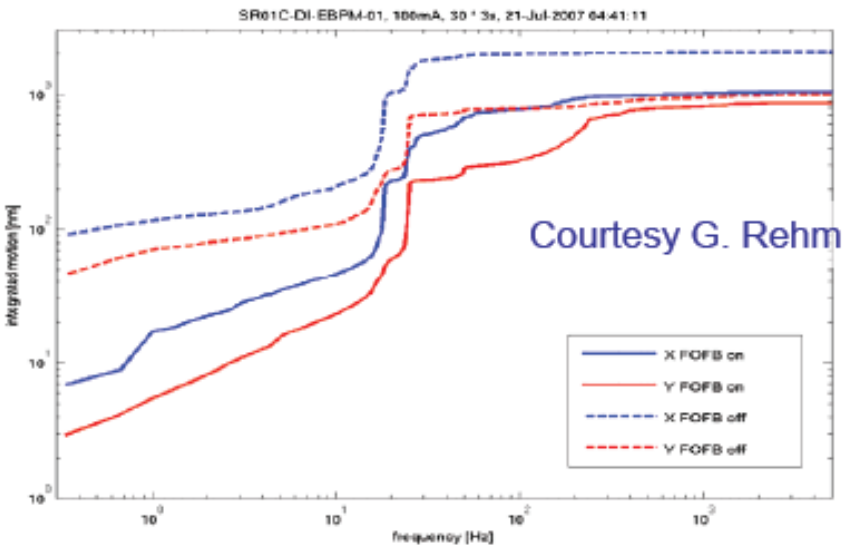
The present Ring & the components in the FOC system allows us to <u>assess these effects</u> by introducing certain 'reductions' or 'degradations' and to do subsequent measurements



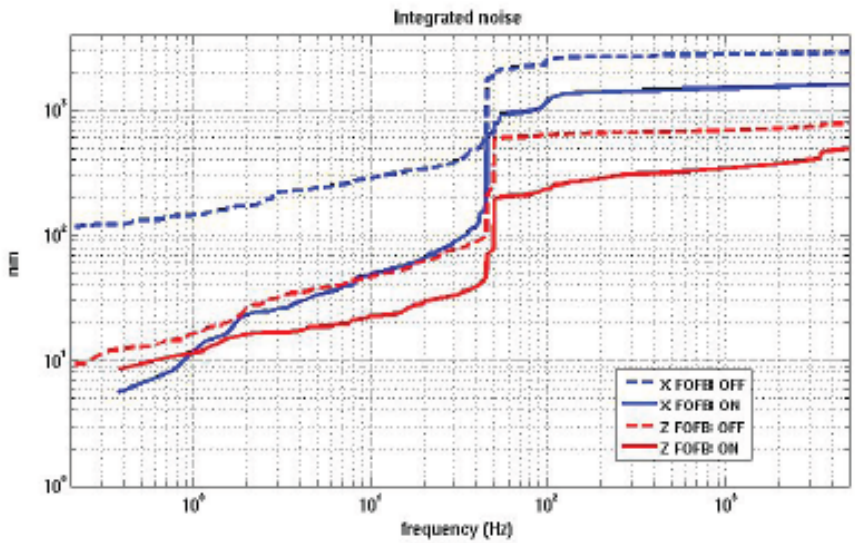


Fast Orbit Feedback System Status

- Needs and requirements are machine specific:
  - No unique solution for orbit feedback system designs
  - Achieved performances are generally good enough to meet user requirements



DIAMOND cumulated PSD in a straight



SOLEIL cumulated PSD in a straight

N. Hubert - 2009

Acknowledgments

• I would like to thanks all involved with orbit feedback community for me sharing your work in this workshop

• My special thanks to following on whom I imposed to provide me slides/ information in a short time -

- Guenther Rehm – Diamond Light Source
- Nicolas Hubert – Soleil Synchrotron
- Kees Scheidt – European Synchrotron Radiation Facility
- Changhor Kuo – Taiwan Light Source

• I was not able to mention work for several light sources around the world, and I apologise.

Thank You