The SLS storage ring: status and options

Andreas Streun, PSI/GFA

- **Storage ring performance status and upgrade**
- **FEMTO seen from the storage ring**
- **Options to create shorter pulses**

"LSY - quo vadis" – Meeting, Wettingen, April 4th, 2006

Storage ring status and improvements

- Beam stability: status & performance
- Beam position control upgrade program
- Brightness increase: coupling suppression
- Hard X-ray source: super bends
- Polarization switching (PolLux)

Beam Stability

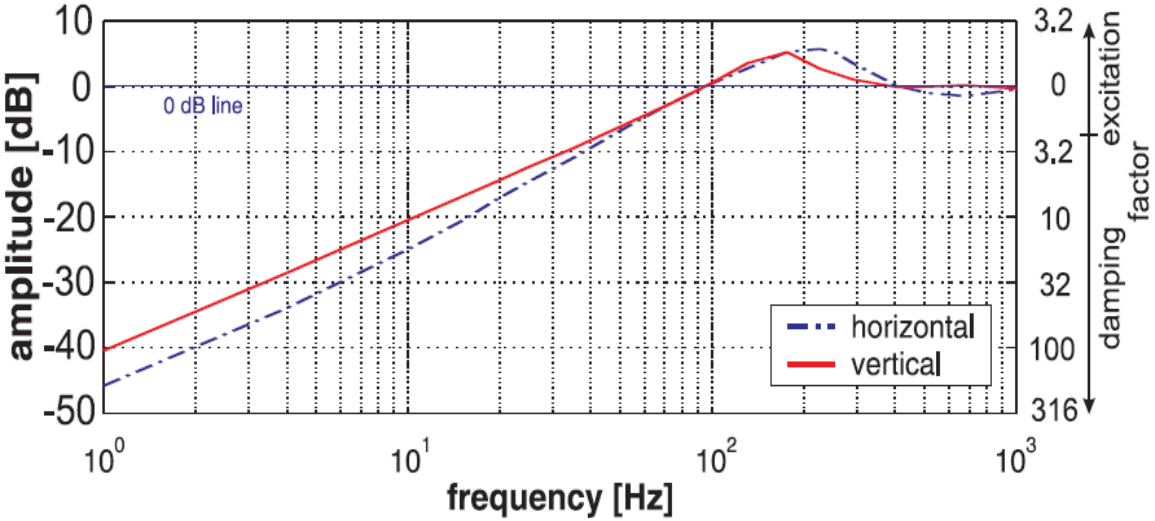
FOFB (Fast Orbit FeedBack)

Resolution: 300 nm (~σ/30)

Frequency: <100 Hz

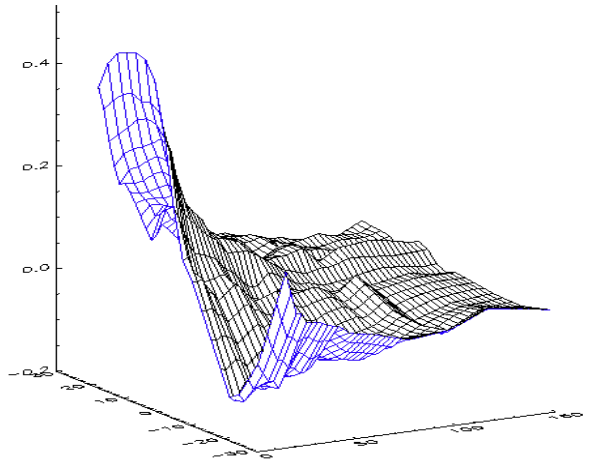
Availability: 98%

+ X-BPM integration (1 Hz):
hor. & vert.:X06S/PX, X10S/PX2
vert. only: X04S/MS, X07D/POLLUX



Attenuation vs. frequency, Ref.: T.Schilcher et al., Commissioning and operation of the SLS FOFB, Proc.EPAC-04, p.2523

IDFF (Insertion devices feed forward)

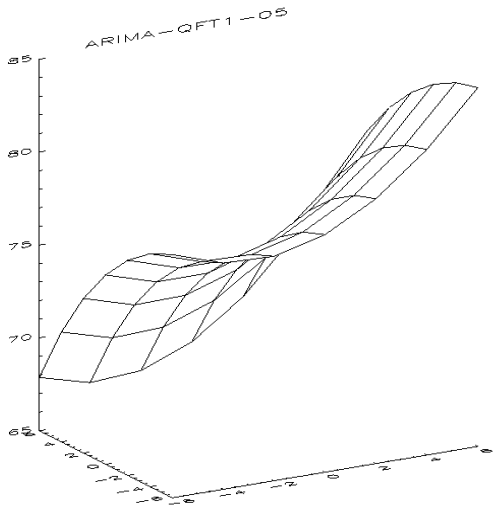


← for orbit....

X11M corrector CVU1
current vs. gap and shift

... and tune →

Femto quad QFT-1 current
vs. hor. & vert. tune shifts
(for compensation of modulator)



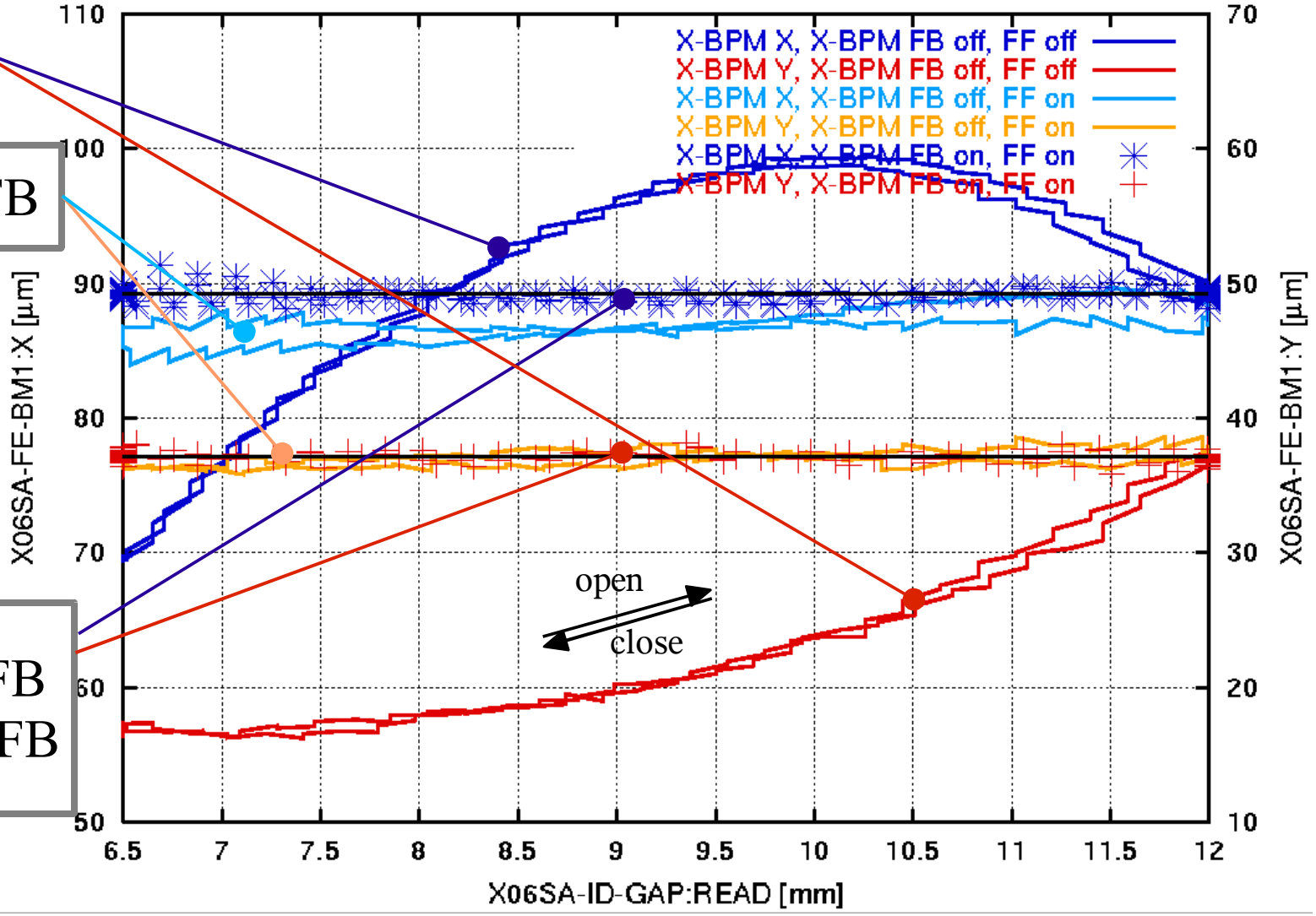
Photon Beam Stabilization by FOFB, IDFF & XBPM-FB

FOFB only

IDFF & FOFB

X06SA
(U19 Danfysik)

IDFF & FOFB
with XBPM-FB



Beam position control upgrade program → 2010

BPM system operates at its limit (computing power, hardware, network)
Design age ~ 10 yrs: no spare parts, risk of failures due to aging

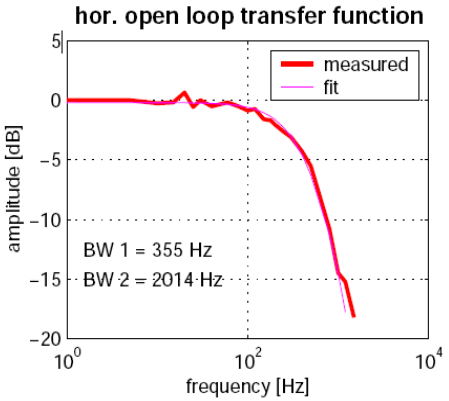
New system: possibilities ↔ requirements ?

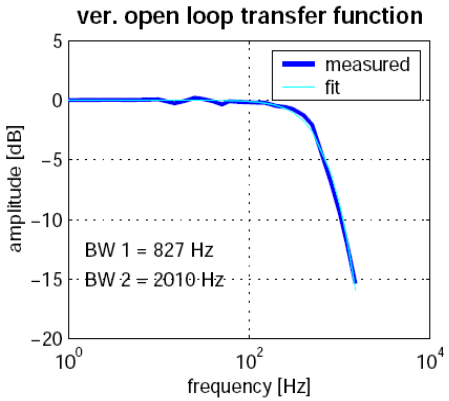
Higher resolution: 300 nm → 100 nm ?

Higher frequency: 100 Hz → 200 Hz ?

limited by vacuum chamber & magnet iron →
T.Schilcher et al., Commissioning of the FOFB at SLS, Proc.PAC-03, p.3386

⇨ Local kHz FB for IR-beamline ?





XBPM upgrade: 1 Hz → 4 kHz (new electronics) → 100 Hz feedback

+ VUV-BPMs: residual gas monitors (under development)

Brightness increase

Emittance coupling $g = \varepsilon_y / \varepsilon_x$

mainly caused by orbit excursions inside sextupole magnets

Measured values (from scraper experiments): $g = 3\ (\pm 1)$ ‰ with zero orbit

$g = 8\ (\pm 3)$ ‰ with user orbit

Brightness = Flux / $(4\pi\, \varepsilon_x^2\, g)$	diffraction << source (E > keV)
Brightness = Flux / $(\varepsilon_x\, \lambda)$	diffraction >> source (E < keV)

Activities

Optical coupling measurement (April 2006): resolution → ~ 1 ‰

Modelling and optimization using skew quadrupoles

Target

Coupling control down to $g = 1$ ‰

⇒*Realignment of all beam lines to zero orbit*

Lifetime vs. coupling theoretical studies (M.Böge & A.Streun, **1999**)

BEAM LIFETIME STUDIES FOR THE SLS STORAGE RING

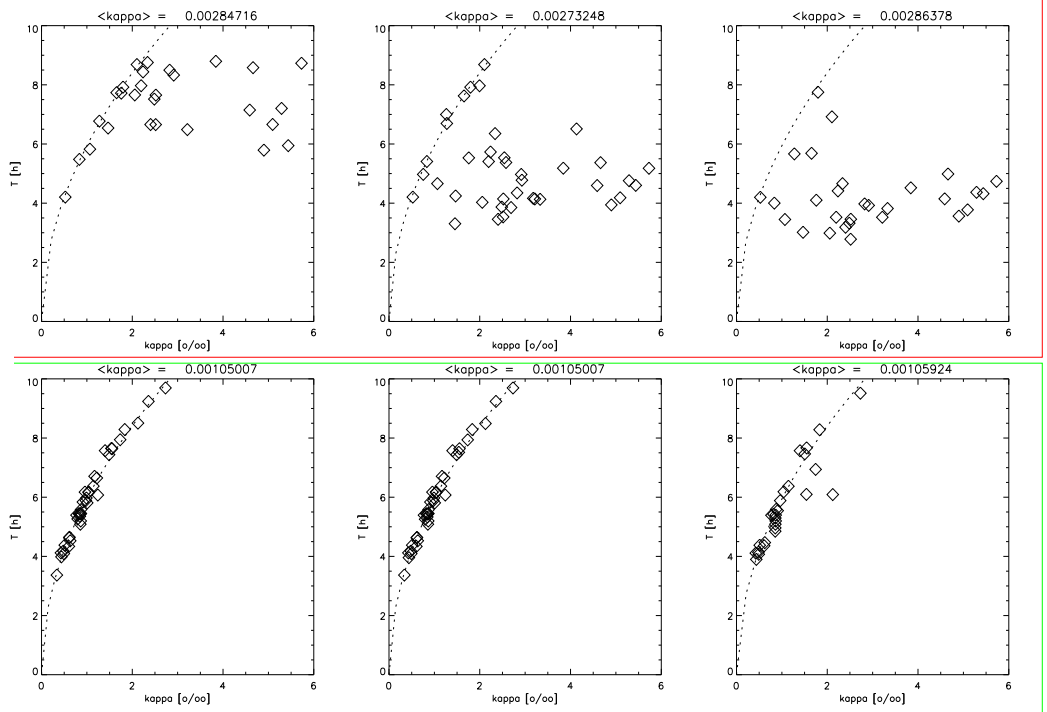
M. Böge, A. Streun, Paul Scherrrer Institut, 5232 Villigen, Switzerland

Touschek lifetime vs. coupling for D2A optics

before...

coupling suppression

... after



gap full height: 32mm 4mm 3mm

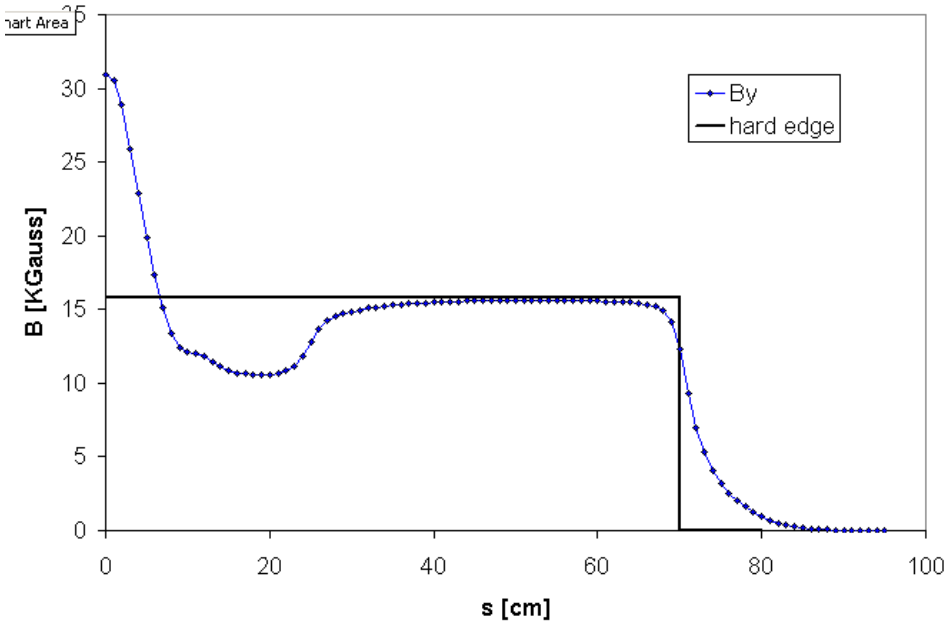
Dotted curve: T = 188 hrs x sqrt(kappa) for the error free lattice

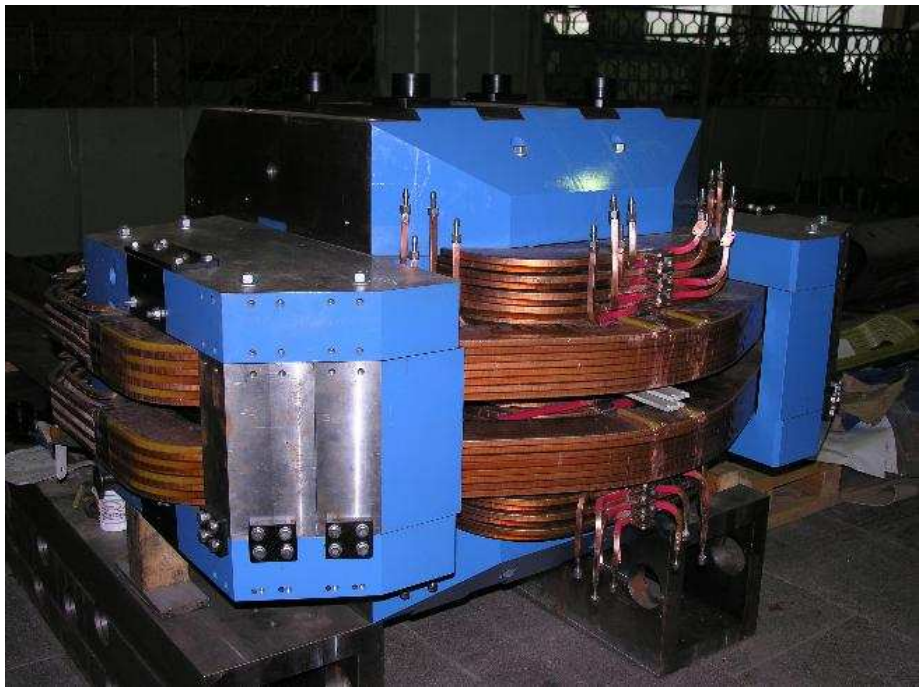
50 seeds, misalignments 0.3mm/0.025mrad girder, 0.1mm joints, 0.05mm/0.1mrad elements (rms), Vrf = 4.2 MV

Hard X-ray source

3 super bends for beam lines X02DB/TOMCAT, X06DB/PX3, X10DB/SuperXAS

Manufacturing:	Budker Institute	done
Transport:	Novosibirsk PSI	soon
Measurement:	PSI magnet group	May/June
Installation:	July-shutdown	

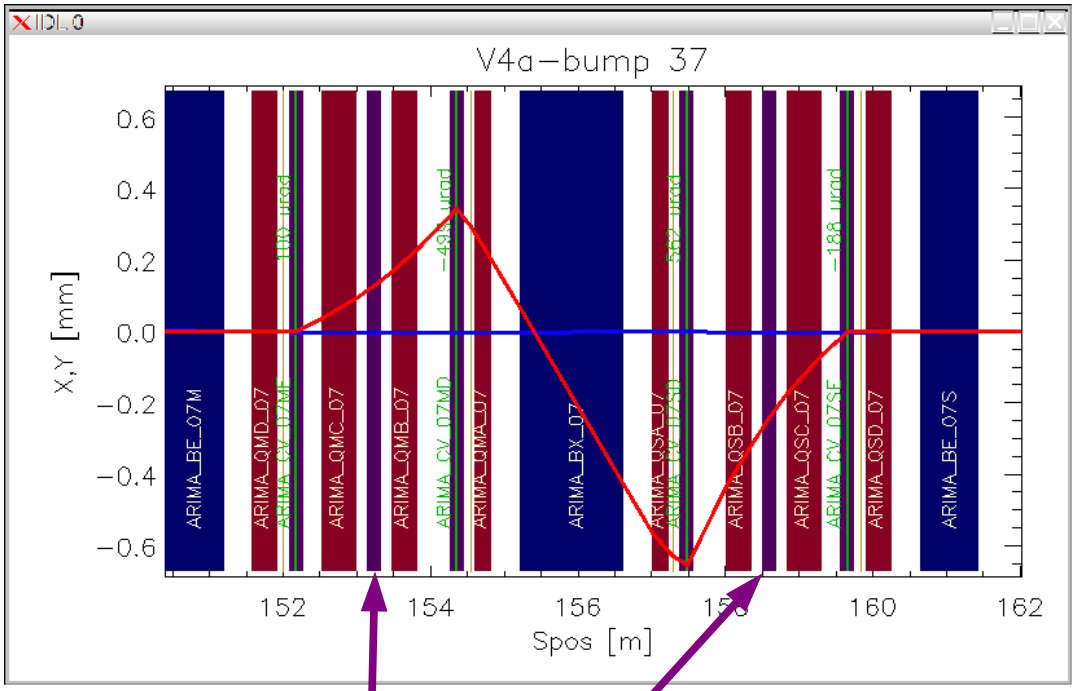




Polarization switching at PolLux (M. Böge)

Vertical bump ±300 μrad at few Hz

Frequency spectrum < 100 Hz for FOFB !



Orbit excursion in **sextupoles**

➔ **coupling increase by 0.8‰**

⇩

Coupling Feed Forward:

☺ all sextupoles have additional coils to be used as **correctors** or **skew quads**

⇨ Get power supplies for available sextupoles SF-07M, SF-07S

⇨ Drive local skew quadrupole ramps

➔ **coupling increase by 0.08‰ ✔**

FEMTO

- storage ring modifications
- filling patterns
- bunch length measurements

FEMTO storage ring modifications

Jan. 04 **QLH-05 replaced,shifted** ⇨ lattice periodicity 3 → 1

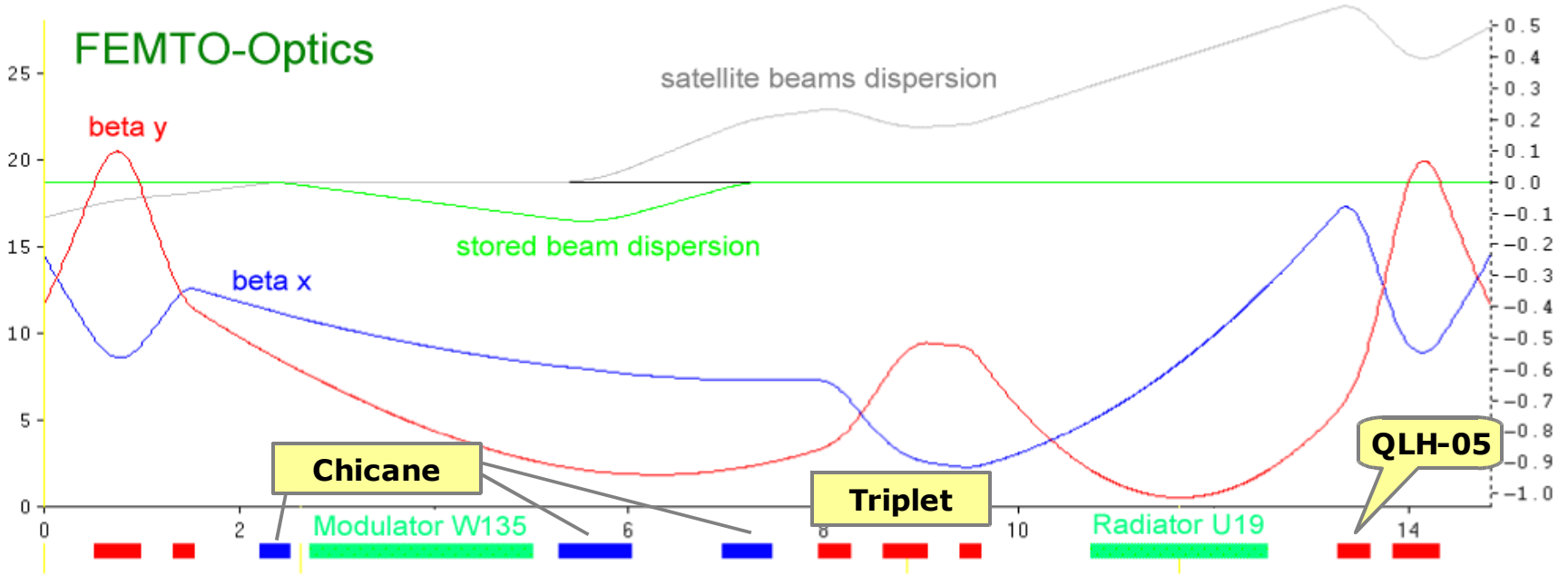
Apr. 04 **triplet and radiator** ⇨ vertical tune shift +0.5

Jan. 06 **new triplet, QLH-05 shift** ⇨ ok

Apr. 06 **chicane and modulator** ⇨ circumference +7.4 mm, RF –13 kHz

narrow vacuum chamber ! ε 5.0 → 5.5 nm (Mod. open) ... 7.2 nm (closed)

modulator field roll-off ! *lifetime & injection efficiency ?*



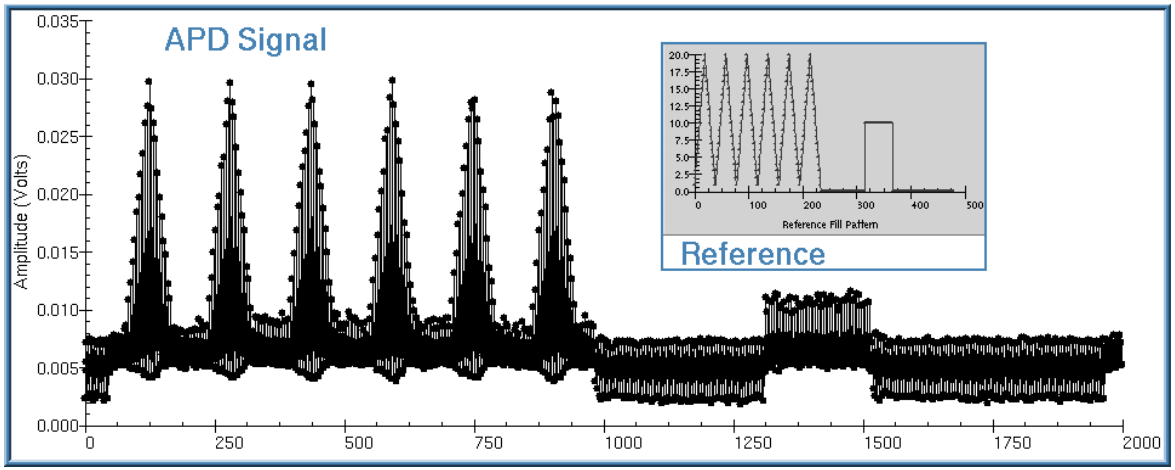
Filling patterns

- 480 buckets
- 400 mA max. current
- single bunch injection

⇒ **arbitrary filling patterns**

filling pattern feedback

(B.Kalantari)



Restrictions

general: gap in train (~ 100 empty buckets), single bunch current < 8 mA

harmonic cavities:

ON current < 400 mA, bunch length (rms) ~ 50 ps

OFF current < 200 mA , [→ upgrade: multi bunch feedback system]
bunch length (rms) ~ 15 ps (for *bunch* currents < 1.2 mA)

Present user mode:

350 mA in 330 or 390 buckets + single bunch (few mA) in gap

Possibilities (to be tested!)**:**

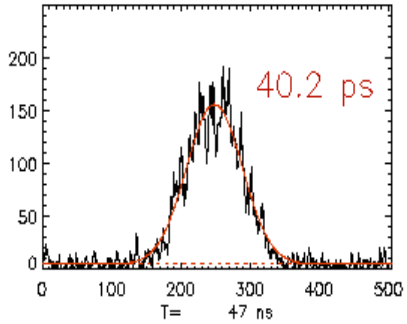
e.g. 60 bunches, 16 ps spacing, ~100 mA + FEMTO bunch (✔)

Bunch length measurements in hybrid mode

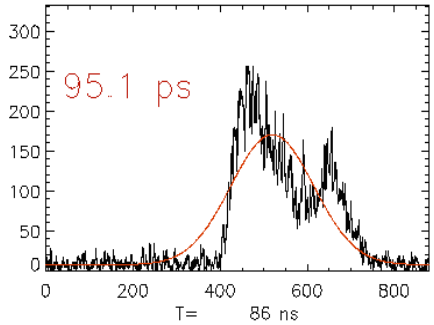
350 mA bunch train in 390 / 330 / 280 of 480 buckets

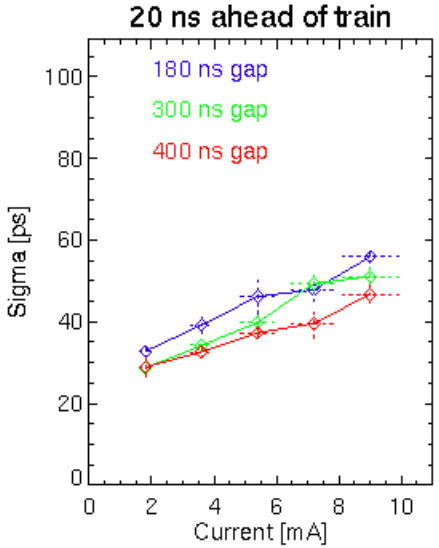
+ single bunch:

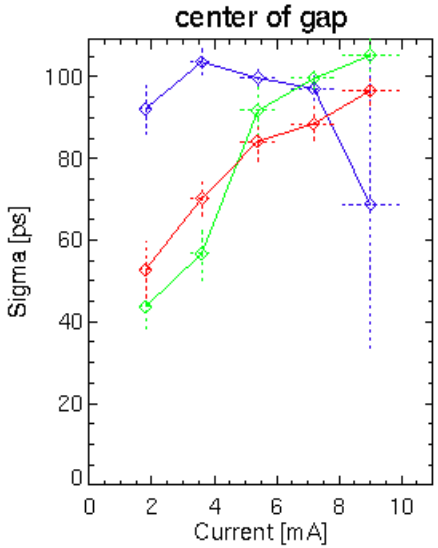
20 ns ahead of train:

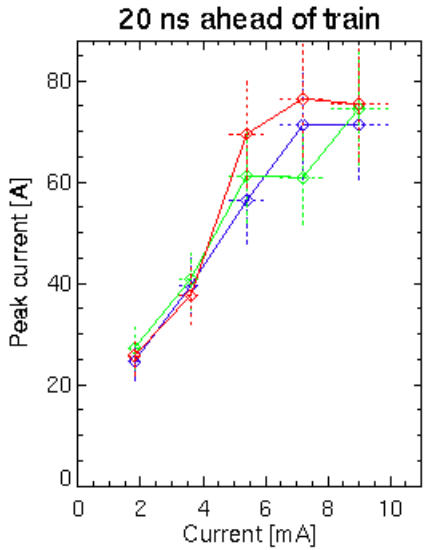


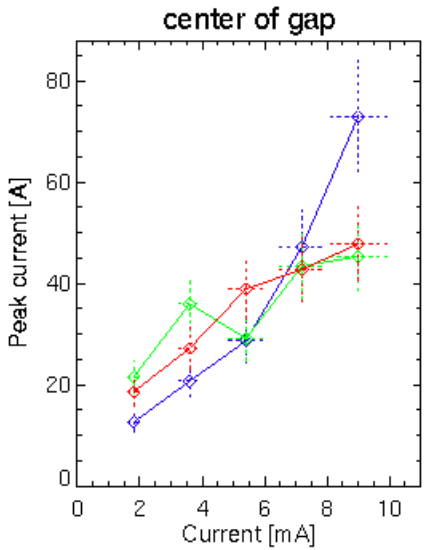
center of gap:











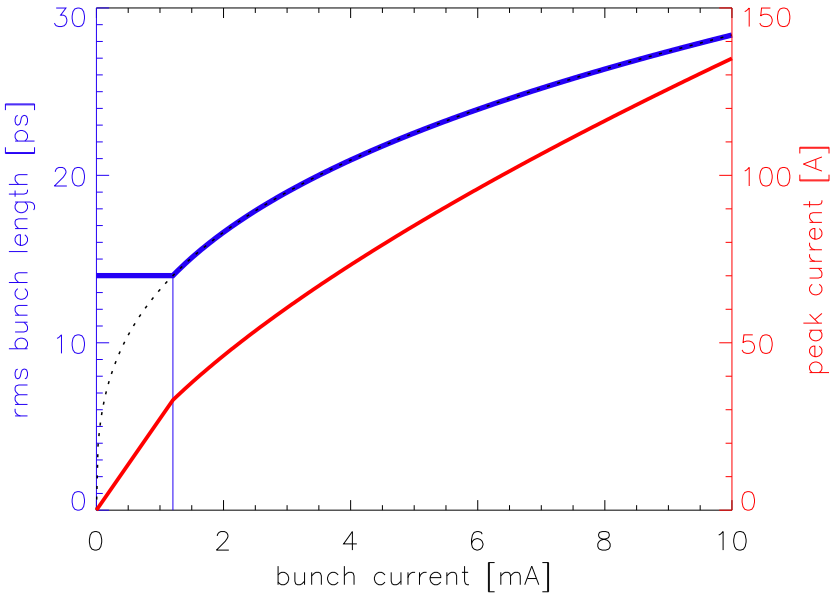
Single bunch length measurements

Bunch lengthening with current

Bunch length ~ current $^{1/3}$ above threshold

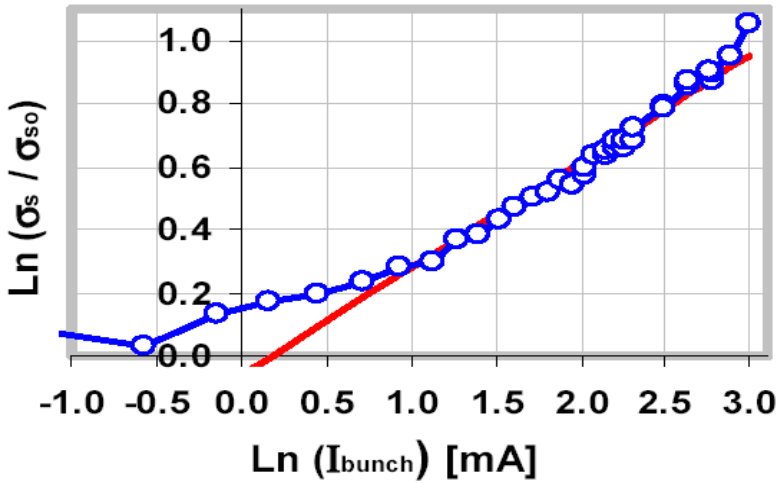
Peak current ~ current ^{1} below threshold

$I_{peak} = I\, T_o / [\sqrt{(2\pi)}\, \sigma_t]$ ~ current $^{2/3}$ above threshold

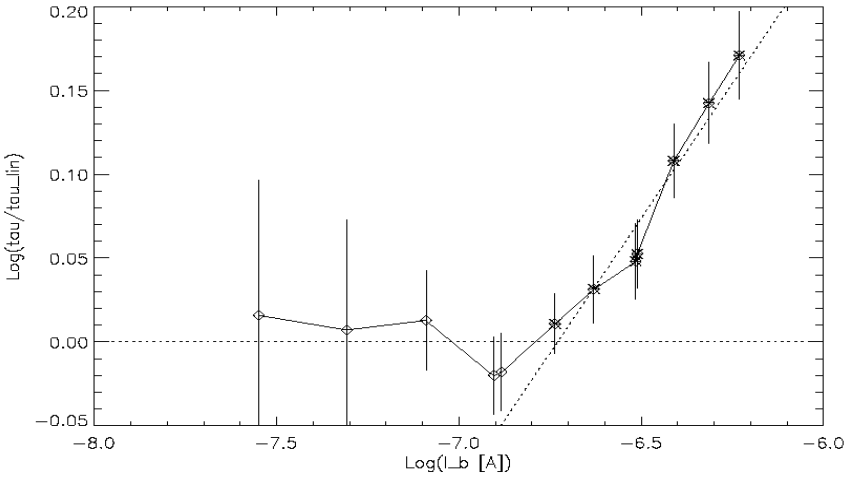


SLS Measurements of bunch lengthening:

Streak Camera (2004)
Threshold = **1.2 (± 0.2) mA**
Exponent = **0.34 (± 0.01)**



Touschek Lifetime (2001)
Threshold = **1.19 (± 0.05) mA**
Exponent = **0.32 (± 0.05)**

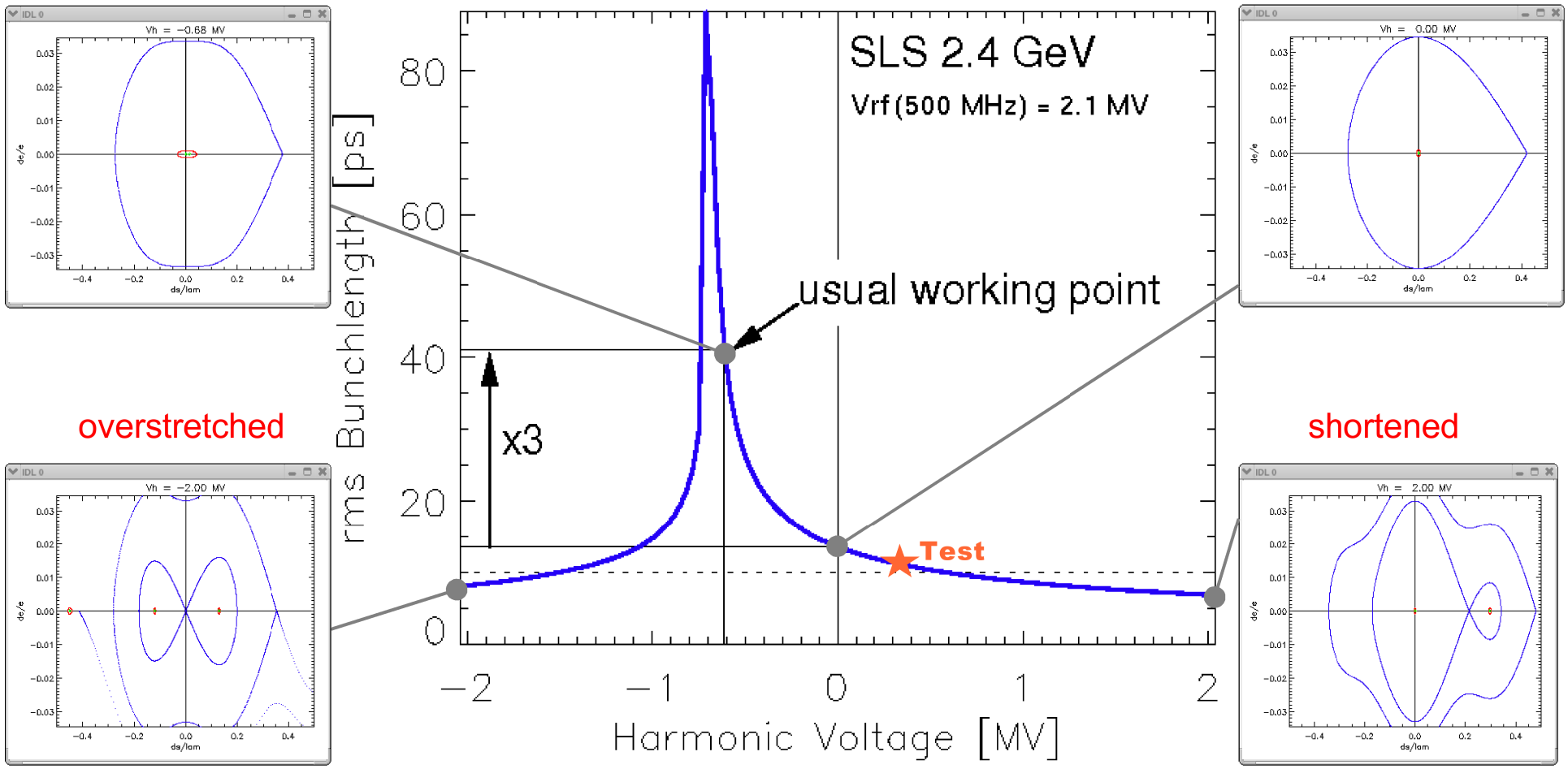


Short pulse options for SLS

- Reverse operation of harmonic cavities
- Low alpha optics
- Crab cavities for X-ray pulse compression

Harmonic cavity for bunch shortening

Cavity limits: $|V_h| < 1.5$ MV ⟶ bunchlength ~ 8 ps (rms)

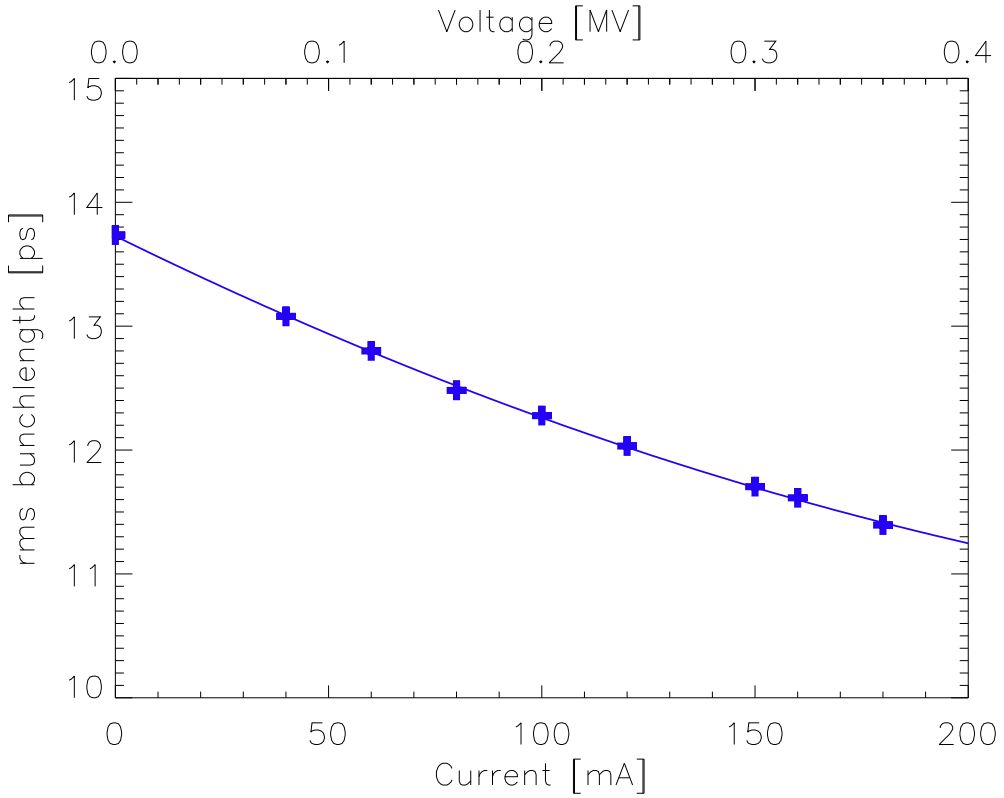


SLS bunch shortening test

$$V_h\,[\mathrm{MV}] = -\,0.133 \cdot I\,[\mathrm{mA}] / \Delta f\,[\mathrm{kHz}]$$

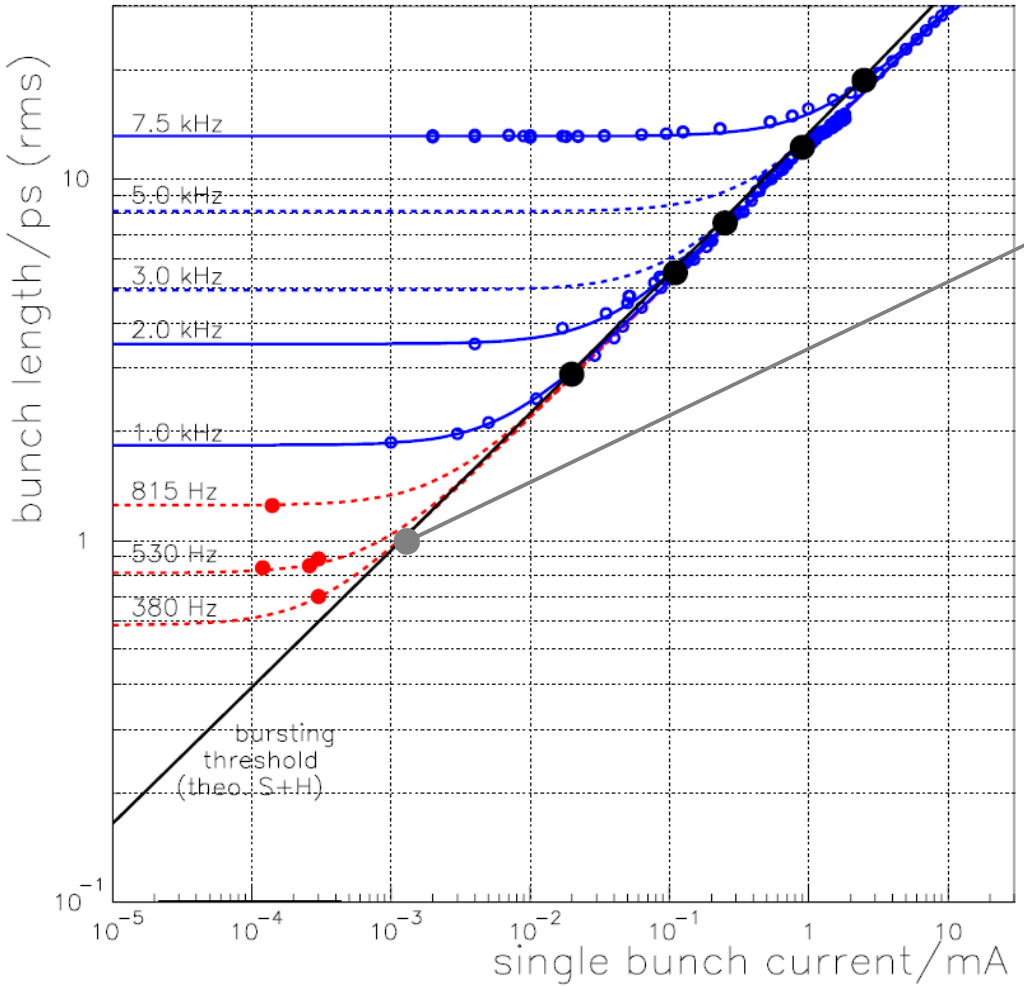
Detuning $\Delta f = -\,70$ kHz
max. current 185 mA
min. bunchlength 11 ps

(M.Pedrozzi, 25.3.2003)



Low alpha-optics (bunchlength ~ $\sqrt{\alpha}$)

BESSY-2 Measurements



Scaling:

Bunchlength > Current$^{3/8}$

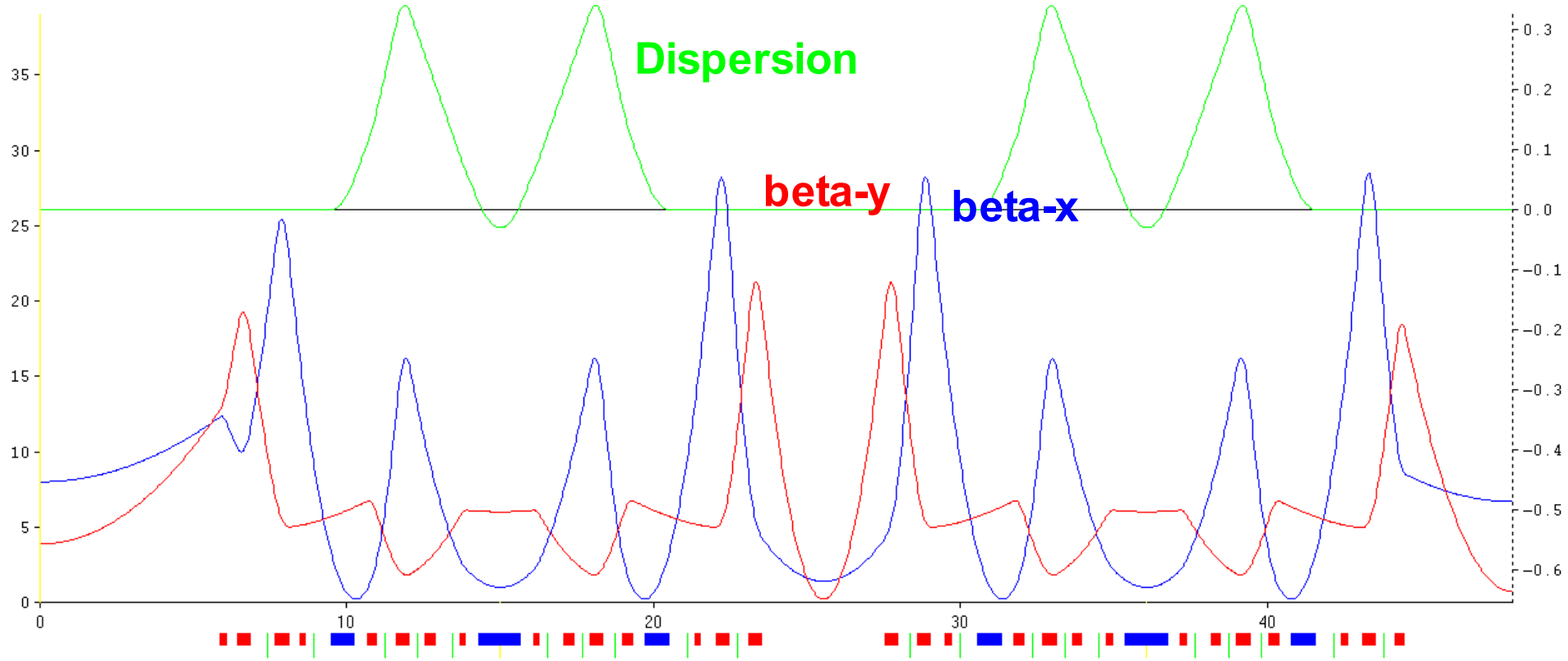
< 1 ps → < 1μA

← streak camera

← coherent THz radiation

J.Feikes et al.,
Sub picosecond electron bunches in the BESSY storage ring,
Proc. EPAC-04, p.1954

Low alpha optics for SLS (draft)



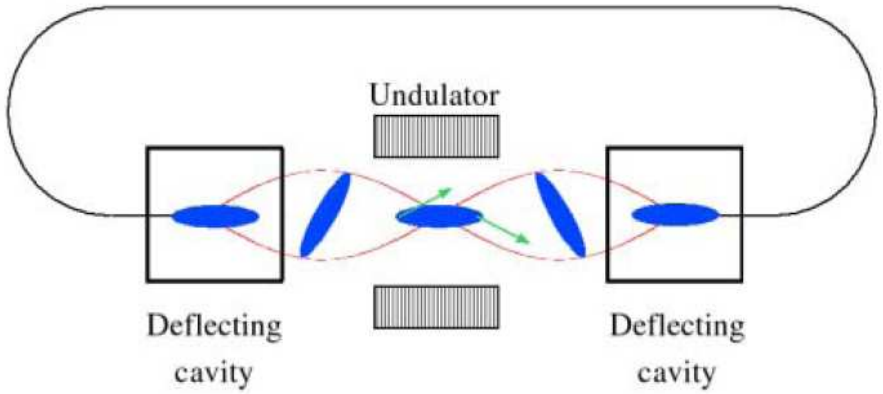
1/6th of lattice shown

α = 5.7x10^{-5} (~1/10th of normal value)

bad lattice performance, feasibility questionable ☹

Crab cavities for X-ray pulse compression

Transverse deflecting cavities create correlation y' (t)



K.Harkay et al., *Generation of short X-ray pulses using crab cavities at the APS*, Proc. PAC-05, p.668

Compression of correlated X-rays y(t) through position dependant path lengths

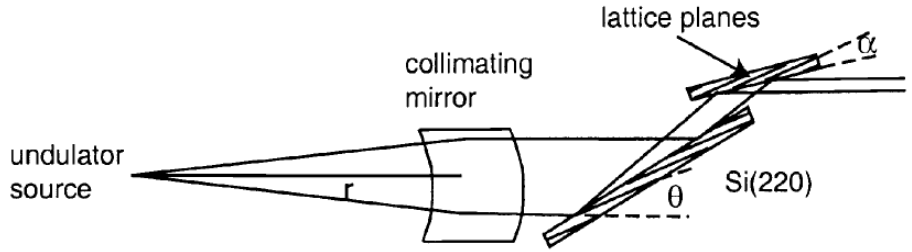


Fig. 3. Optical scheme for pulse compression with a collimating mirror and a double asymmetrically cut crystal monochromator.

A.Zholents et al., *Generation of subpicosecond X-ray pulses using RF orbit deflection*, NIM A 425 (1999) 385

rms X-ray pulse length > E / (2π f_c V_c) (ϵ_y / β_y + σ_{rad}^2)$^{1/2}$

APS (7 GeV) layout: 2 x 7 s.c. cavities (2.8 Ghz, total V_c = 4 MV) for < 1 ps

Application to SLS: high β_y in undulator and coupling suppression
V_c ~ 1...1.5 MV → 2 x (2...3) s.c. cavities → space ?

Comparison of short pulse options

Method	σ_t	Efficiency*	Feasibility	to do
normal + 3HC on	50 ps	1	✓	----
normal + 3HC off	14 ps	0.5 [1]	✓	[multi-bunch feedback]
FEMTO	0.1 ps	10^{-9}	✓$	---- (commissioning)
3 HC reversed	8 ps	~1	? ☺	tests & MBFB
Low alpha	1 ps	0.001	? 😐	optics design
Crab cavities	1 ps	~1 ?	? ☹$	space, crab-cavities, high-beta optics, X-ray optics

* efficiency 1 = flux from ~ 350 mA

⇨ Decision on priorities

⇨ R & D (Beam Dynamics, RF, Diagnostics)

⇨ predictions of feasibility, performance and efforts

⇨ SLS upgrade projects...