PAUL SCHERRER INSTITUT

SWISS LIGHT SOURCE

SLS experience

- Optics measurement and correction -

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Introduction

- What has been measured and corrected at SLS
  - Beta function measurement with quadrupole variation (tune response), SVD based correction
  - Linear coupling measurement with orbit response, SVD based correction using skew quads (Partial LOCO)
  - Dispersion
    - Hor.: No explicit correction (correction through beta correction)
    - Ver.: Correction together with coupling

      Skew quads at dispersive and non-dispersive section
  - Nonlinear optics correction with pre-defined theoretical knobs (combination of sextupoles)

- Recent activities
  - (Full) LOCO
  - Turn-by-turn
  - Girder re-alignment

SLS main parameters

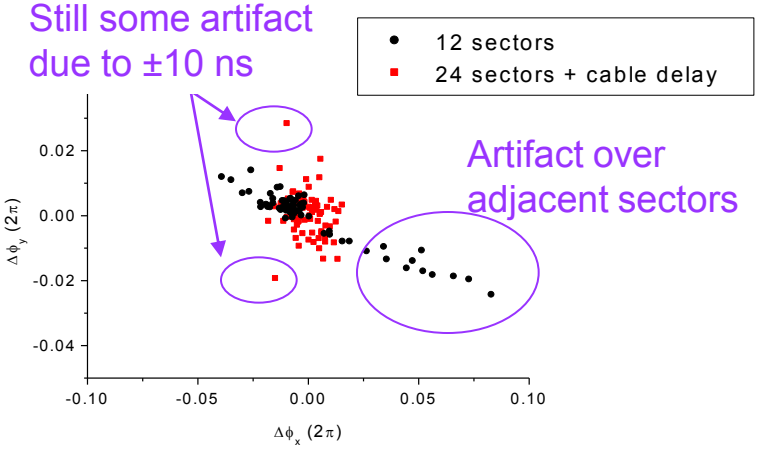
Lattice	12 TBA
Circumference	288 m
Beam energy	2.4 GeV
Emittance (H / V)	5~6.8 nm / ~2 pm
Beam current	400 mA
Number of beamlines	18

TBT at SLS

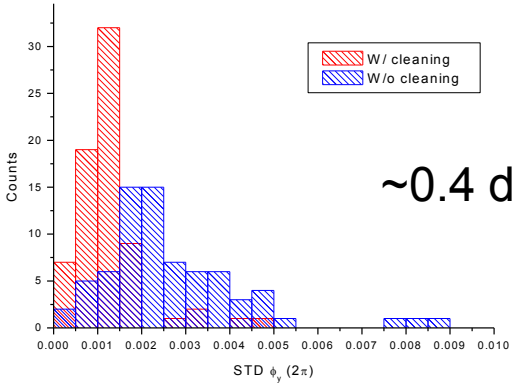
- Synchronization
  - 12 sectors accommodating 72(+1) BPMs in total
    → 24 sectors (80 ns → 40 ns Sector-to-Sector delay)
  - Fine trigger adjustment with proper cable delay within sectors
  - Another cable delay (S-to-S) installation soon to overcome the timing system resolution
    ±10 ns (50 MHz) → <~1 ns synchronization
- DAQ and analysis
  - One click application to collect
    ~2000 turns × 10 times
  - Beta-beat software package from LHC including SVD data cleaning

Difference phase advance measurement and model

Still some artifact due to ±10 ns



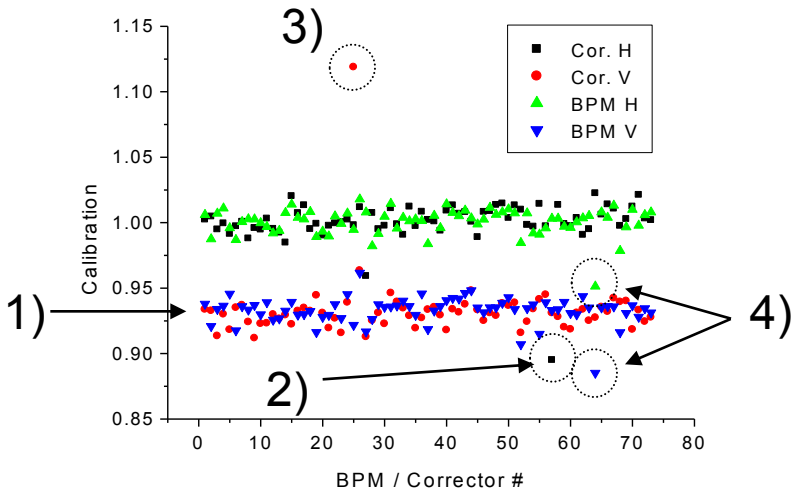
Phase measurement quality
(Statistical error, 4 measurements)

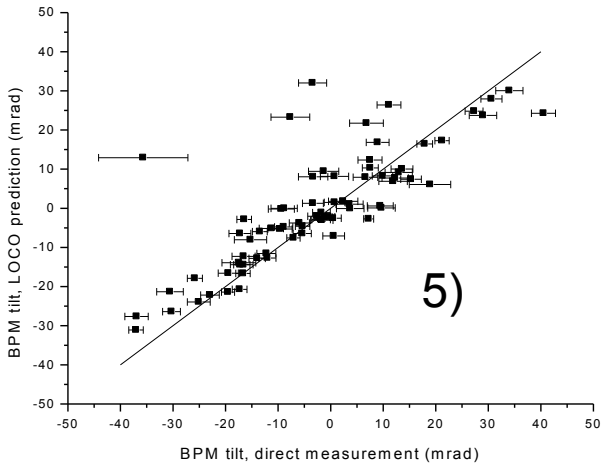


~0.4 deg with Q'~5

LOCO at SLS

- LOCO
  - Revealed wrong BPM/corrector calibration and BPM tilt
    1) Calibration in the vertical plane ~15%(!), BPMs and/or correctors, recalibrated
    2) A horizontal corrector PS with broken ADC board, repaired
    3) Calibration of a vertical corrector, known problem of the different magnet from others, recalibrated
    4) Calibration of a BPM in both planes, recalibrated
    5) BPM (electronic) tilt showed good agreement with a direct measurement

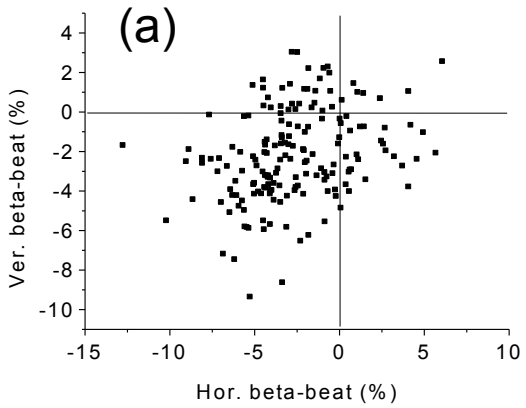


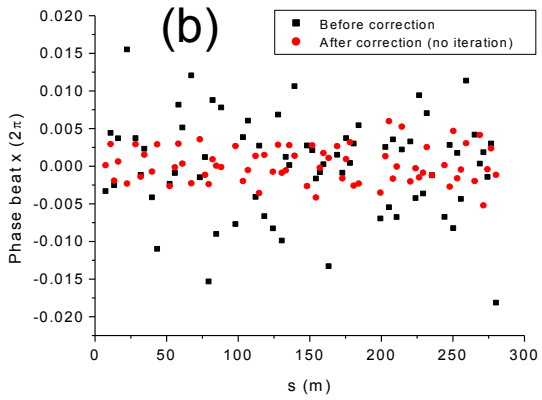


Direct measurement
- Run fast orbit feedback
- Vary horizontal feedback reference
- Observe corresponding hor. and ver. corrector strength
- Find BPM tilt assuming no tilt error in corrector

Linear optics

- Q variation
  - Tune response to small Q variation
  - Found to contain unknown/systematic error[(a)], high SVD cut - E.V.~35/177
  - Nevertheless, enough correction for operation: 3-4% beta-beat in both planes
    - Enable to use the optics model for FOFB, coupling corr. and nonlinear opt.
- LOCO & Turn-by-turn
  - Correction with LOCO, check with TBT[(b)]
  - Iteration and more systematic comparison planned



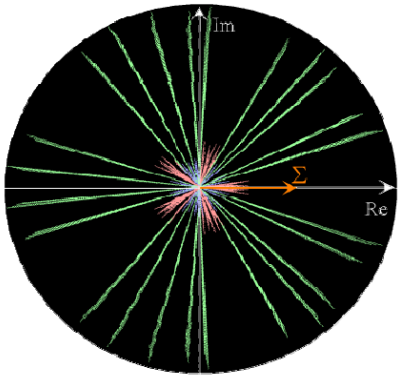


* Optics was detuned at the time of these measurements

Nonlinear optics

Sextupole symmetrization

$$h_{jklmp} \propto \sum_n^{N_{sext}} (b_3 L)_n \beta_{xn}^{\frac{j+k}{2}} \beta_{yn}^{\frac{l+m}{2}} D_n^p e^{i\{(j-k)\phi_{xn}+(l-m)\phi_{yn}\}}$$



Sextupoles in symmetric *families*:

- $\mathrm{Im}\,(h) = 0$ by lattice symmetry
- design: optimized for $\mathrm{Re}\,(h) \rightarrow 0 \;\forall\; h$.

⇨ Auxiliary sextupoles breaking the symmetry

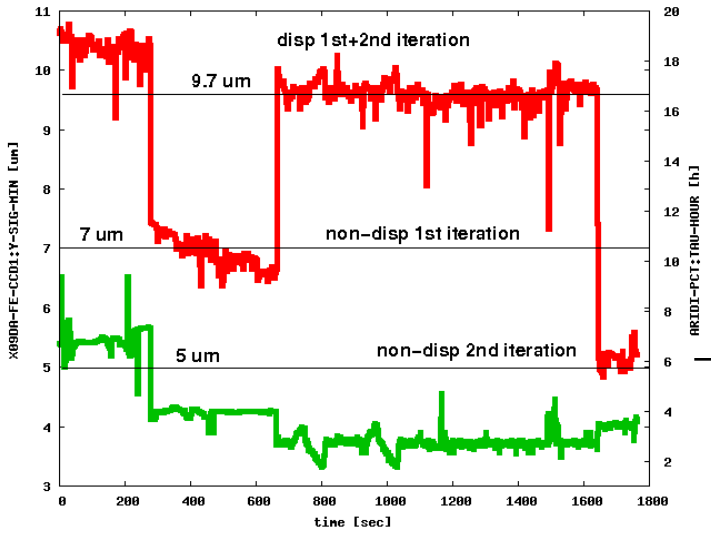
- compensate parasitic $\mathrm{Re,Im}\,(h) \neq 0$.
- first step: do *empirical* optimization
- ≥9 knobs required for Re and Im of
  h_{21000}, h_{30000}, h_{10200} and h_{10020} and $\Delta\xi_x = 0$
- $h_{10110} \propto h_{21000}$ and $\Delta\xi_y \propto \Delta\xi_x$ (SLS: all aux. sext. at same $\beta_x\, \beta_y\, \eta$)
- 12 auxiliary sextupoles installed

⇨ energy acceptance 2% → 3%: 30% lifetime increase

- auxiliary sextupole strength ~ 3% of SF strength

Coupling

- Recent record <2 pm, 15.03.2011
  - By updating all machine knowledge!



$\sigma_y \sim 5\ \mu m$
$\beta_y \sim 13.6\ m$
$\varepsilon_y \sim 1.8\ pm$
(including dispersion contribution)

Girder re-alignment

Dynamic alignment system

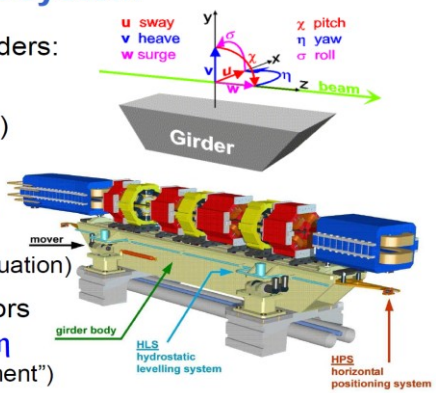
5 mover motors and encoders:
⇒ set and read **u v χ η σ**

Hydrostatic levelling (HLS)
⇒ read **v χ σ** (*slow...!*)

Horizontal sensors (HPS)
⇒ read **u η**
(requires HLS data for evaluation)

BPMs with position monitors
⇒ reconstruction of **u v χ η**
("beam based girder alignment")

no control: **w**

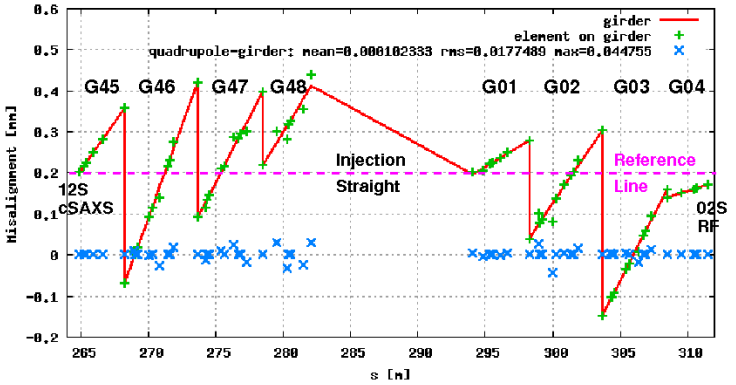


+ coupling correction !

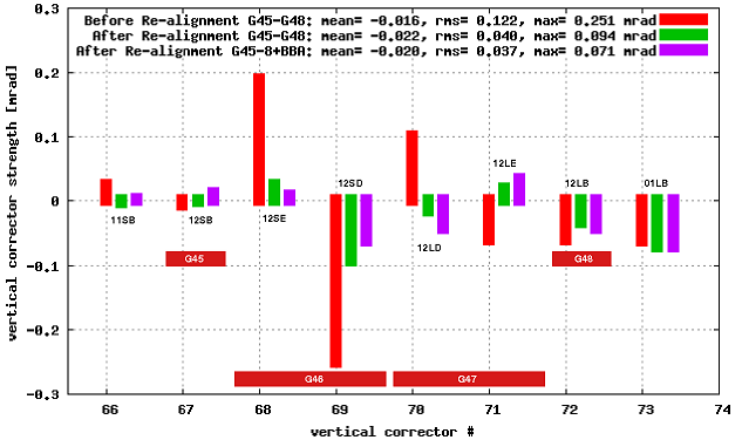
Girder re-alignment system operates with beam and fast orbit feedback running!

Result on sector 12:

Measured misalignment for realignment input



Significant reduction of corrector strength!



Summary and Outlook

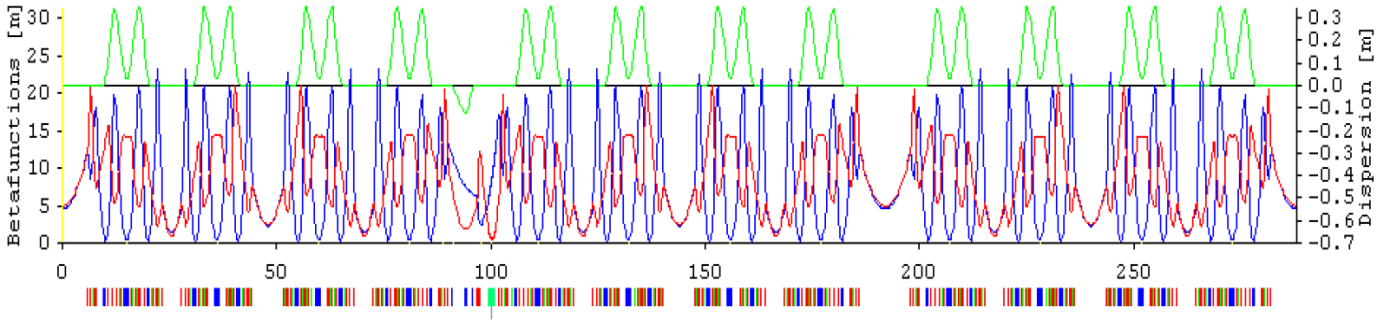
- SLS experience
  - State-of-the-art optics
  - Always good to employ several methods to cross-check!
  - Recent achievements
    - TBT and LOCO are introduced
    - Vertical emittance below 2 pm
    - Girder realignment (on going), significant reduction of corrector str.
- Still a lot of plans and on-going stuffs
  - R&D of beam size monitor with better resolution *
  - Orbit manipulation to correct coupling and ver. dispersion together *
  - Utilize turn-by-turn for coupling and nonlinear optimization
  - etc…

* TIARA WP6 related

Backup slides

SLS lattice

The Swiss Light Source SLS



- 12×TBA lattice, 288 m circumference, 2.4 GeV
- 5.0...6.8 nm emittance (dep. on ID status)
- 400 ±1 mA top up operation
- User operation since 10 years; 18 beam lines
- Upgrades: laser slicing & 3 super-bends
- 1 micron photon beam stability at front ends
- 3 pm rad vertical emittance (0.05% coupling)

  Obsolete!

Beam size monitor

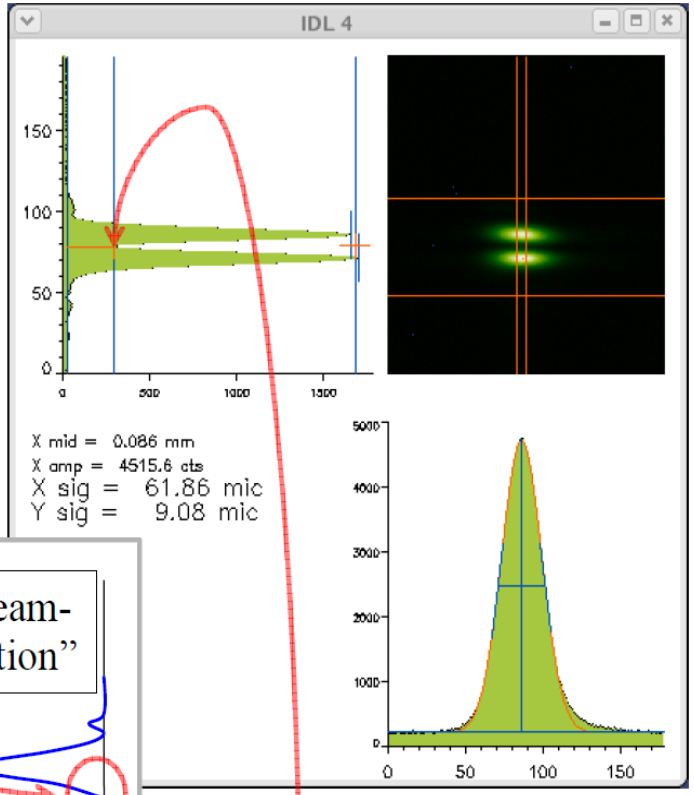
The π -polarization method*):

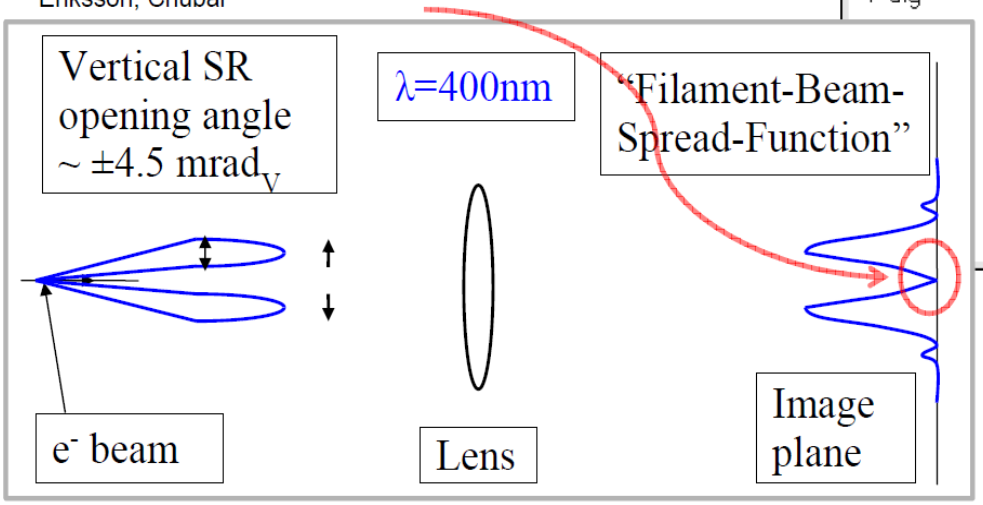
An image of the beam is formed from vertically polarized visible-UV synchrotron radiation.

A π phase shift between the two radiation lobes ==> $I_{y=0}$=0 in "FBSF"

(FBSF =filament beam spread function)

*) Old idea springing from MAX-lab, see EPAC'96 Andersson, Eriksson, Chubar





Finite vert. beam size ==>

Non-zero central intensity

Multipole correctors

Versatile Sextupoles

all 120 sextupoles were delivered with H&V corrector coils
⇨ make skew quadrupoles and auxiliary sextupoles

120 sextupoles in 9 families:

SF(24), SD(24), SE(24) → **chromaticities**

SSA(12), SSB(12), SMA(6), SMB(6), SLA(6), SLB(6) → **D.A.**

SD, SE, S∗B: **72** H&V correctors → **orbit correction**

S∗A: **24** skew quads (η=0) → **betatron coupling**

SF: **12** skew quads (η>0) → **vertical dispersion**

12 auxiliary sextupoles → **resonance suppression**