Summary of machine design, commissioning and operation tools at HBSLS

Guimei Wang

Brookhaven National Laboratory, April 27, 2017

U.S. DEPARTMENT OF ENERGY | Office of Science

High-Brightness Synchrotron Light Source Workshop, April 26-28, 2017

Advances in Machine Design, Commissioning and Operations

3 talks

Design:
Modern Tools and Techniques for Designing Advanced Accelerators
Michael Borland (APS)

Commissioning and operation:
Beam Stability: How to Meet Users' Requirements
Christoph Steier (ALS)

Beam-based Software for Light Source
James Safranek (SLAC)

https://indico.bnl.gov/conferenceDisplay.py?confId=2938

Modern Advanced Tools and Techniques for Designing Advanced Accelerators (M. Borland)

- Important aspects of effective design and modeling tools
  - Physics
  - Integration and workflow
  - Throughput (e.g., efficiency, **paralle**lism)
  - Continuous improvement
- Good workflow is essential to productivity, sophisticated simulation
- Modeling through design, construction, commissioning
- Universal simulation tool to integrate various functions

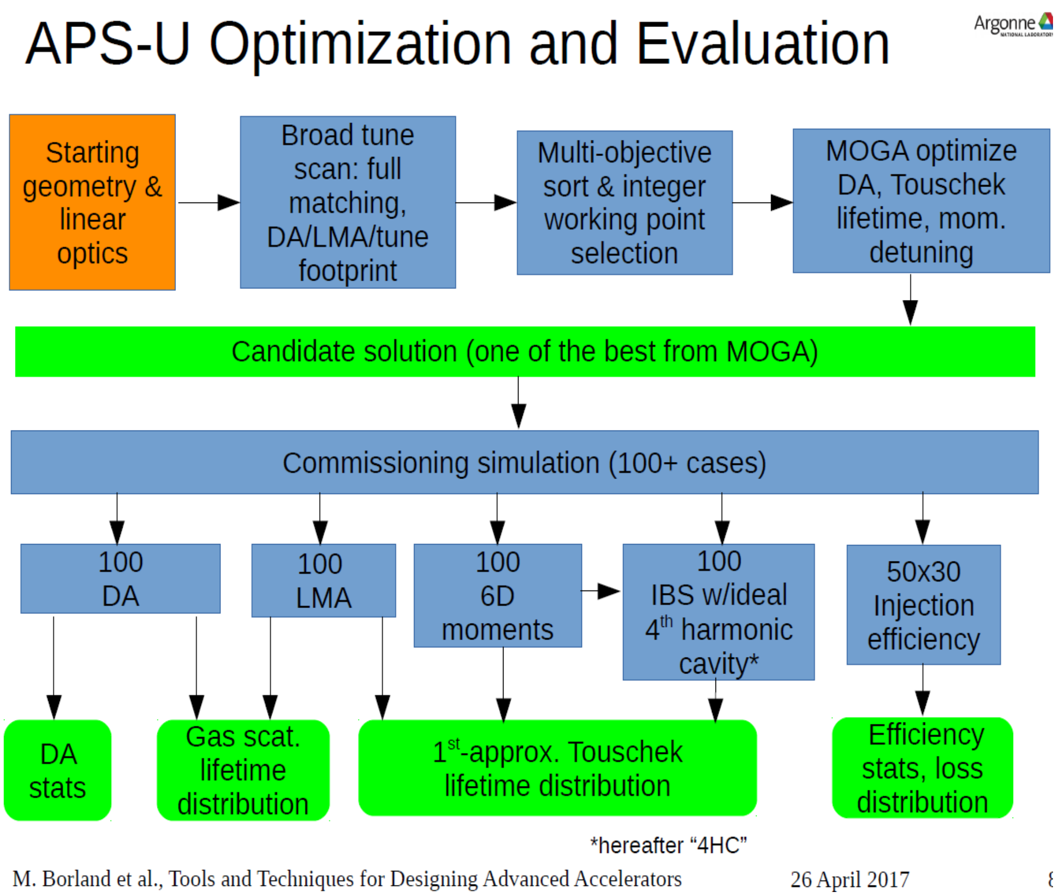
Key APS Software Used for APS-U Sims.

Argonne

- `elegant/Pelegant`: accelerator design; single-particle and collective beam dynamics; MPI-based parallelism
- SDDS library: (parallel) file I/O using self-describing data
- SDDS toolkit: generic, scriptable data processing/display
- `geneticOptimizer`: generic cluster-based MOGA optimization
- `ibsEmittance`: intrabeam scattering
- `touschekLifetime`, etc.: lifetime calculations
- `sddsbrightness`, `sddsfluxcurve`, etc.: x-ray calculations
- `clinchor`: point-particle multibunch instabilities with arbitrary fill patterns
- Open source, multi-platform

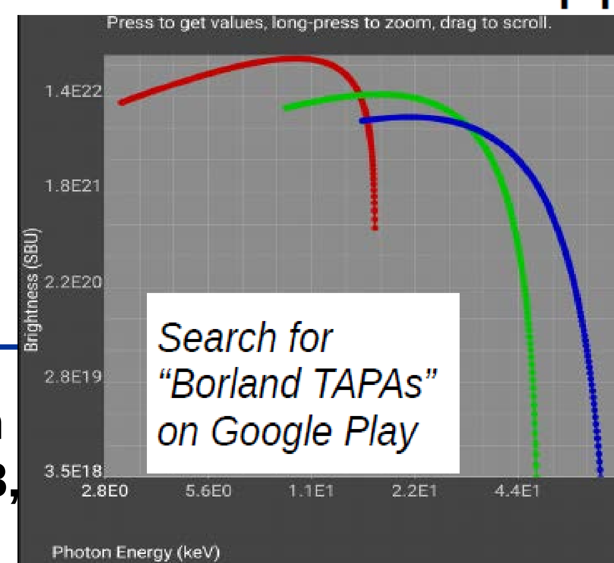
M. Borland et al., Tools and Techniques for Designing Advanced Accelerators 26 April 2017 5

Modern *Advanced* Tools and Techniques for Designing Advanced Accelerators (M. Borland)



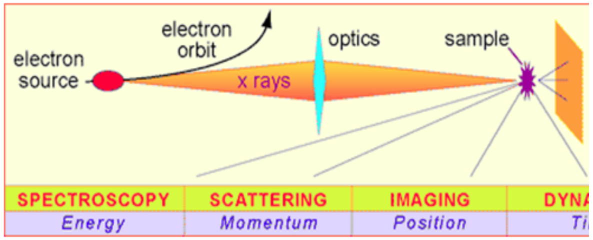
- Receipt to design a new machine from scratch
- Continuous development of new functions
- Beam size variation along bunch train (ALBA, NSLS- II) →Guard bunches or optimized patterns to reduce lifetime variation along bunch train.

TAPAs Android App



Beam Stability (C. Steier)

Beam Stability R…



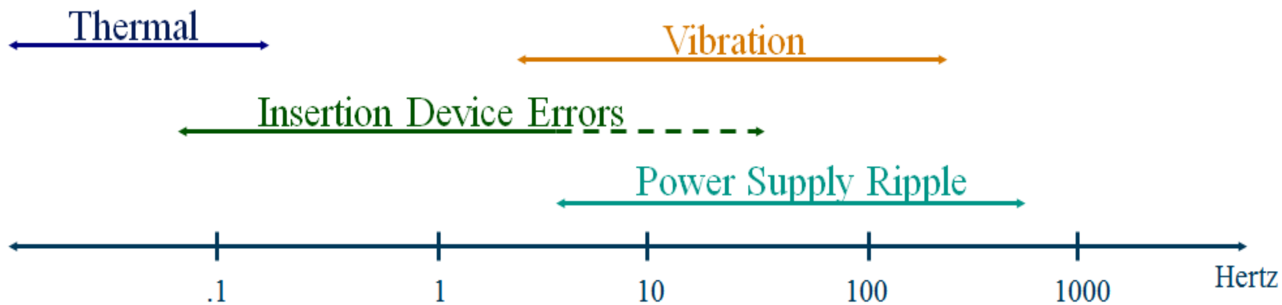
Typical requirements of modern SR user experiments:

Measurement parameter	Stability Requirement
Intensity variation ΔI/I	<<1% of normalized I
Position and angle	<2-5% of beam σ and σ'
Energy resolution ΔE/E	$<10^{-4}$
Timing jitter	<10% of critical time scale
Data acquisition rate	$10^{-3} - 10^{5}$ Hz

BERKELEY LAB

HBLS V

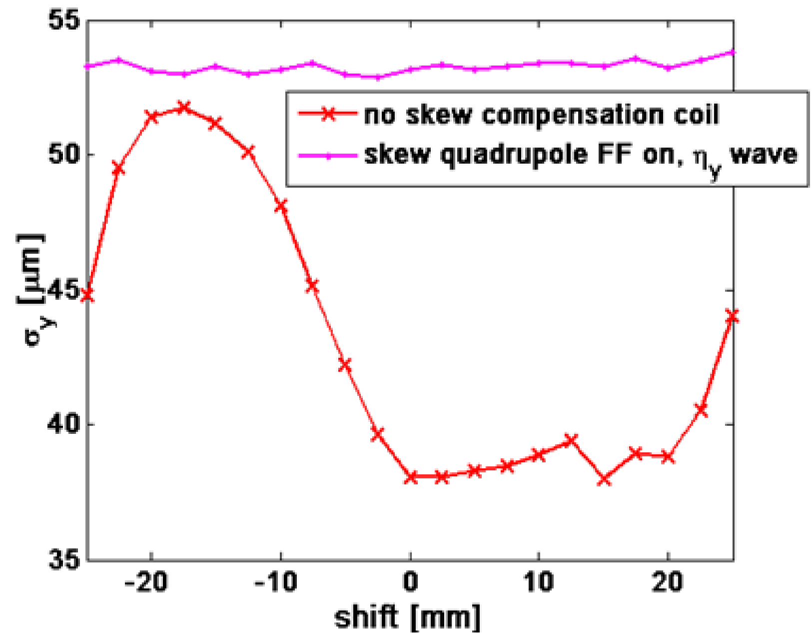
Causes for Orbit Distortions (no F/B)



Frequency	Magnitude	Dominant Cause
Two weeks (A typical experimental run)	±200 μm Horizontal ±100 μm Vertical	1. Magnet hysteresis 2. Temperature fluctuations 3. Component heating between 1.5 GeV and 1.9 GeV
1 Day	±125 μm Horizontal ±50 μm Vertical	Temperature fluctuations
8 Hour Fill	±50 μm Horizontal ±20 μm Vertical	1. Temperature fluctuations 2. Feed forward errors
Minutes	1 to 5 μm	1. Feed forward errors 2. D/A converter digitization noise
.1 to 300 Hz	3 μm Horizontal 1 μm Vertical	1. Ground vibrations 2. Cooling water vibrations 3. Power supply ripple 4. Feed forward errors

Beam Stability (C. Steier)

- Minimize source impacts with quiet site, girder design
- Improvements of air and water temperature stability, PS…
- Orbit stability: global + local, fast (+slow) FB
- Energy stability: RF frequency FB
- Beam size instability: Insertion devices FF



Comments and Questions:

- More demands to add photon BPMs into FB
- Beamline local feedbacks
- Composite FF table (orbit, beta-beat, coupling) vs ID's gap
- Efficiency of local RF & Xray BPM feedbacks: interaction with global Fb? Ways of out coupling different Feedbacks?
- Identify the photon sources instability?

For reference: Whenever an undulator moves, about 120-150 magnets are changed to compensate for the effect (slow+fast feed-forward, slow+fast feedback)

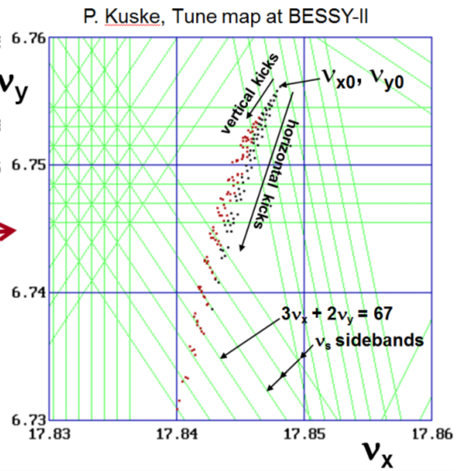
Beam-based Software for LS (J. Safranek)

- Storage ring linear optics correction: orbit response matrix analysis (LOCO*), BPM TbT analysis
- Demanding on beam-based nonlinear dynamics correction
  - Nonlinear dynamics measurement
  - Beam based optimization (tuning): adjust the operating condition to optimize machine performance directly.

Widely used
Nonlinear dynamics measurements

SLAC

- Nonlinear chromaticity
- Closed orbit bump probe
- Tune shifts with betatro
- Tune scans, ($\sigma_{x,y}$, lifetim
- Energy acceptance (τ vs
- Dynamic aperture
- Tune maps



*** J. Safranek, NIM-A 388, 27 (1997).**

Optimization algorithm development at SSRL/SPEAR3

SLAC

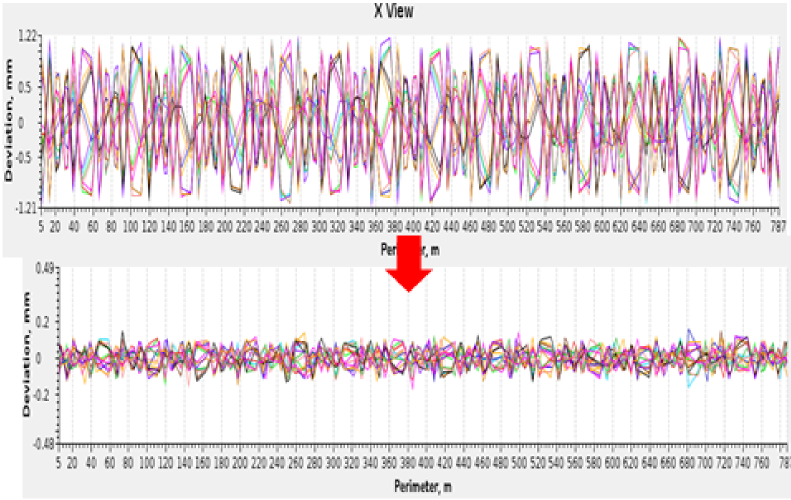
- **Multi-Objective Genetic Algorithm (MOGA or SOGA)**
  - Applied to minimize coupling using 17 skew quadrupoles
  - *K. Tian, J. Safranek, and Y. Yan, Phys. Rev. ST-AB (2014)*
- **Robust Conjugate Direction Search (RCDS)**
  - Applied to coupling, top-off transient, LCLS undulator taper, etc...
  - *X. Huang, J. Corbett, J. Safranek, J. Wu, NIMA (2013)*
- **Particle Swarm Optimization (PSO)**
  - Applied to numerical dynamic aperture optimization (see Xiaobiao's presentation later today)
  - Applied to SPEAR3 coupling correction
  - *X. Huang, J. Safranek, NIMA-D-14-00356 (2014)*

Beam-based Software for LS (J. Safranek)

- Nonlinear dynamics optimization is very important for SR commissioning and operation
- Different algorithms were applied to SR (not limited) online optimization, such as kicker bump matching, Injection efficiency w/ sextupoles, Transport line optics…
- Comments: online<->model, experience with using Machine learning/Neural Network algorithms?

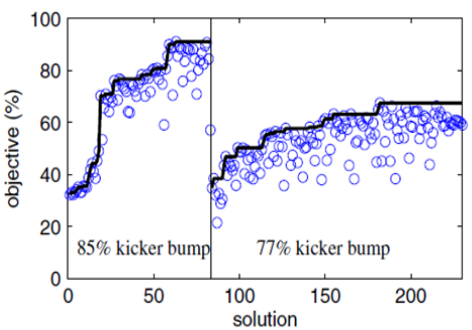
NSLS-II kicker alignment with RCDS method

TBT residual oscillation

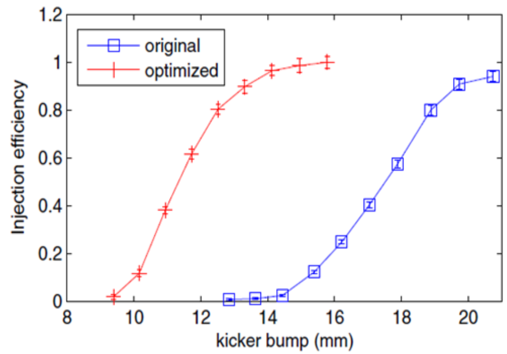


Online dynamic aperture optimization for SPEAR3

SLAC



Optimizing injection efficiency with reduced kicker bump.
Knobs: 8 sextupole knobs – each knob is a pattern of 10 sextupole families that do not change chromaticities.



DA was increased from 15.1 mm to 20.6 mm by optimization.
Momentum aperture (MA) was not affected.

X. Huang, J. Safranek, PRSTAB 18, 084001 (2015)

tbt Xrms VS injection bucket