Implementation of a Diagnostic Pulse for Beam Optics Stability Measurements at FLASH.

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Introduction

High-gain free-electron laser FLASH at DESY [1-3]

> Ultra-short X-ray SASE pulses with a duration less than 30 fs FWHH
> Electron beam can be tuned to energies between 350 MeV and 1.25 GeV (which corresponds to a photon wavelength of roughly 45 nm and 4 nm)
> Laser-driven photoinjector
> Seven 1.3 GHz superconducting accelerator modules (*TESLA-type*)
> 27 m long undulator section

Diagnostic pulse @ FLASH

> FLASH is a user facility → long-term stability is crucial for all connected user experiments
> FLASH1, FLASH2 and sFLASH demand high beam optics stability

> Proposal of a simple procedure to monitor the beam optics routinely and minimally invasive
> Goal: Additional tool for the operators to judge the overall machine stability
> First test measurements have been conducted and presented in [4]

Implementation @ FLASH

> Planned to be deployed during beamtime in the second half of 2015

FLASH

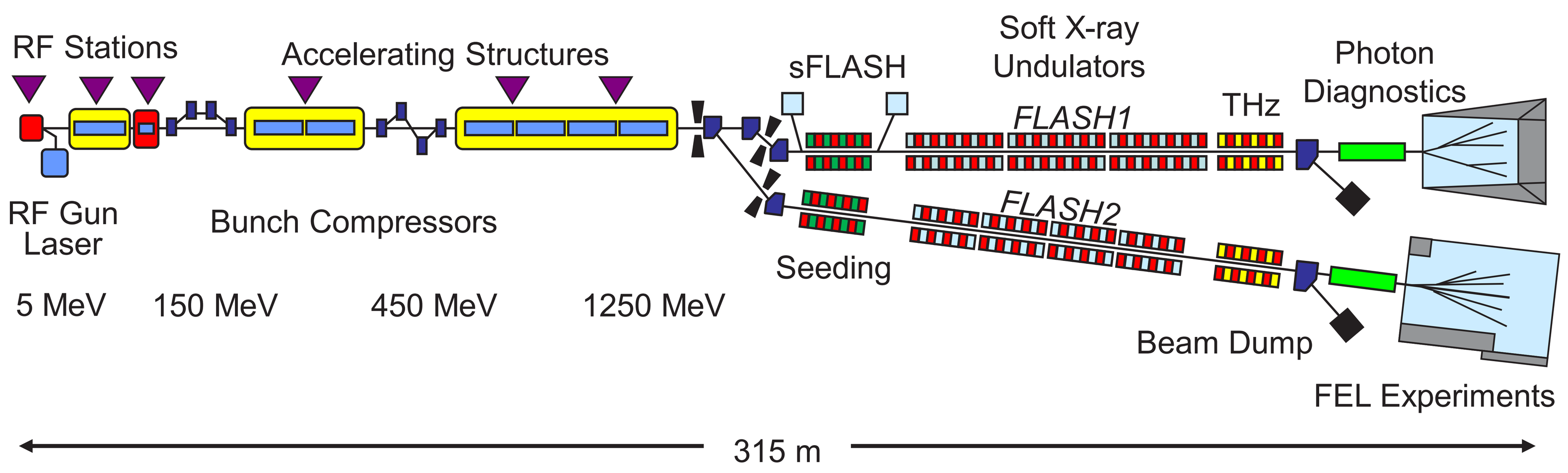

Figure 1: Schematic overview of FLASH with its two beamlines FLASH1 and FLASH2. The beam direction is from left to right. The schematic is not to scale.

Method

Introduction

> Extract beam optics stability information by measuring kicker magnet induced betatron oscillations periodically via all available downstream BPMs
> An online tool analyzes the data. This way a long-term history of beam optics stability can be compiled

Aim of the method

> Reveal the cause of beam optics errors, which lead to symptoms like the loss of SASE signal or a trigger of the machine protection system

Prerequisites

> In order to be able to calculate beam optics related physical quantities from the BPM data it is necessary to induce the oscillations at two different positions along the linac. The distance in phase advance should be close to π/2
> This way R-matrix elements can be calculated

Zero-crossing method

> Another way to obtain the betatron phase advance is to fit the positions of the zero-crossings of the betatron oscillations. This method allows the fast evaluation of the data in steps of π

Implementation Schemes

Two possible schemes

> *Fast kicker scheme*
  > Single bunch kickers
  > Can run in background (minimally invasive)
> *Steerer scheme*
  > Slow steerer magnets
  > Disturbs user operation (invasive)

FLASH

> Dark current kicker at the beginning of the linac
  > Sinusoidal, resonant @ 1 MHz
  > Only usable in single bunch mode
  > Only y-plane

> Slow steerer scheme
  > For every wavelength setting select two suitable steerer pairs
  > Full trajectory fit possible
  > Measurement takes ~5 sec [4]

Scheme	Planes	Extractable quantities
DC-Kicker	y	Ψ_y
Steerer	x,y	$\Psi_l, A_l, \beta_l, \alpha_l, B_{mag}$

Table 1: Two possible implementation schemes for the diagnostic pulse at FLASH. See [4] for details on the extractable quantities.

Software (Backend)

Server / client approach

> Rich DOOCS [5] middle layer server
  > Control / Measure
  > Results / History
  > Settings

Measurement results

> Records long-term history of data and extracted quantities
> Save data for N pre-defined machine regions

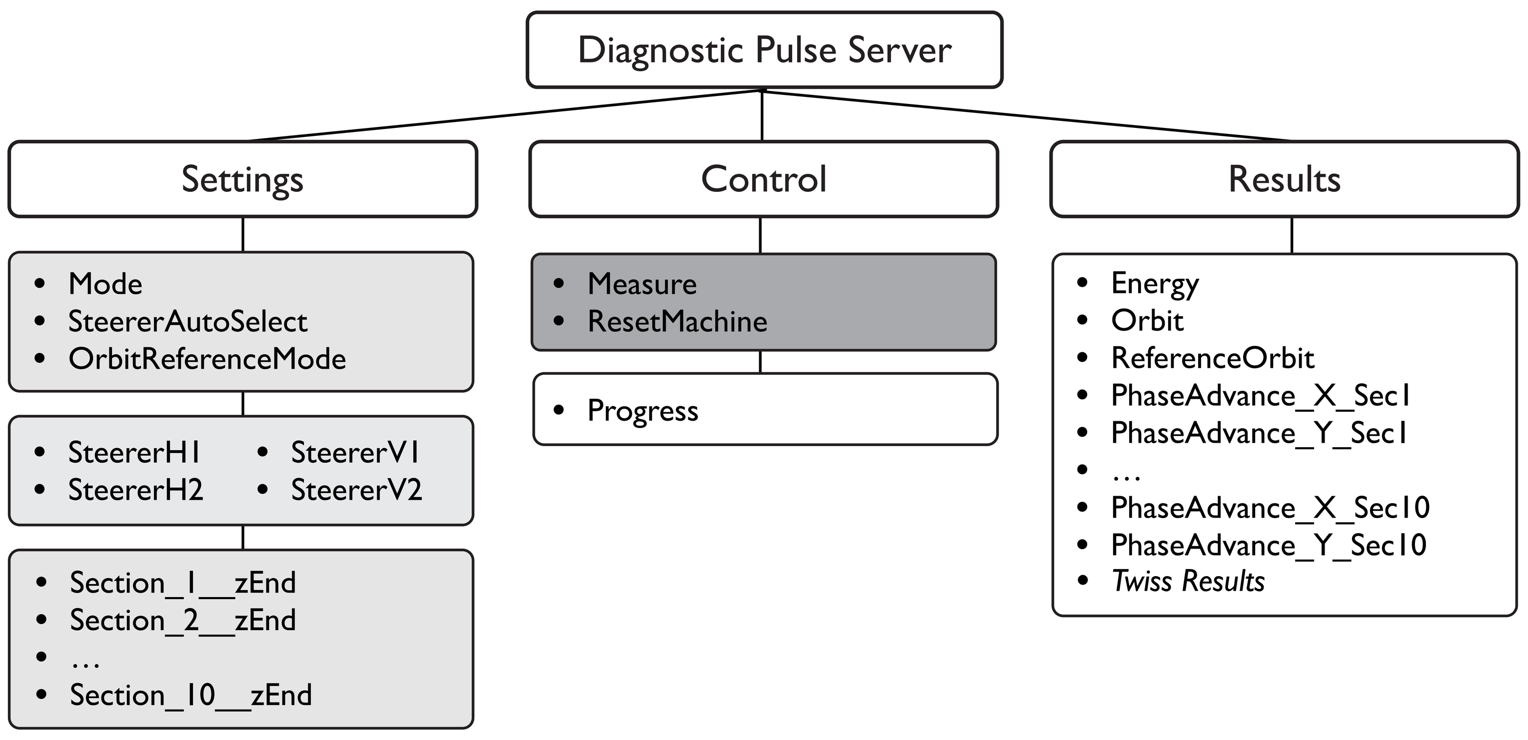

Figure 2: Structure of the DOOCS middle layer server.

Software (Operation)

Server / client approach

> Easy to use jDDD [6] panel
> *One button measurement* (*Steerer Scheme*)
  > Long-term history relies on operator compliance
  > *Idea*: Part of shift documentation
> Control of background operation (*Fast Kicker Scheme*)

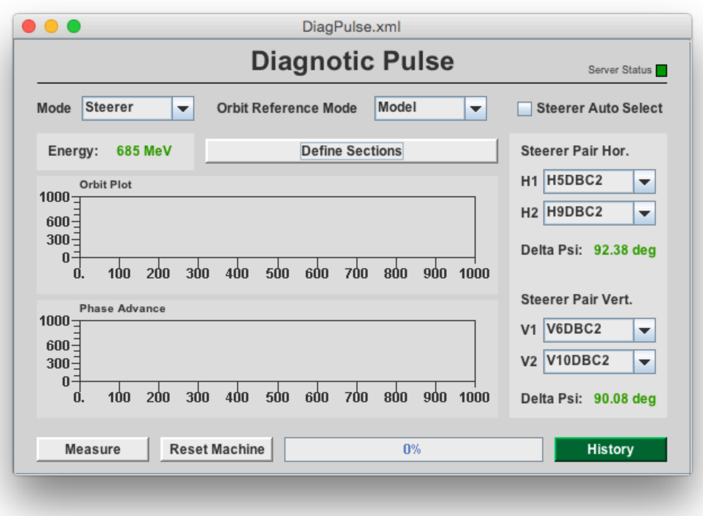

Figure 3: The jDDD-based control panel.

Simulation

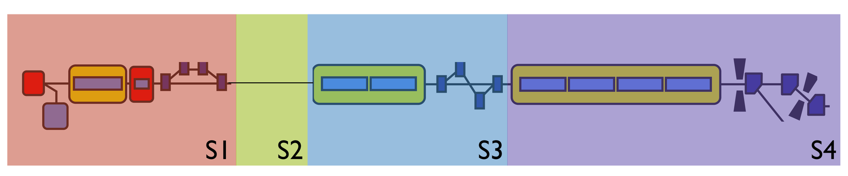

Figure 4: The four FLASH linac sections that were chosen for the test case simulations. **S1**: end of first bunch compressor, **S2**: start of 2nd accelerating module, **S3**: start of 4th accelerating module, **S4**: end of linac. The color coding corresponds to the one used in figures 5 and 6.

ELEGANT based test case simulations

> Simulation of the method using *virtual FLASH*
  > Simulated long-term measurement using ELEGANT [7]
  > DC-Kicker scheme results

Information from history data

> Here: Phase advance in four sections
> Extract unique curve patterns
> Possibility for sophisticated pattern recognition?
> Possibility for abstract / verbal way of presenting the data?

Virtual FLASH

> ELEGANT based simulation tool
> Manipulation of machine parameters *on-the-fly*
> Use DOOCS server routines on the simulated data

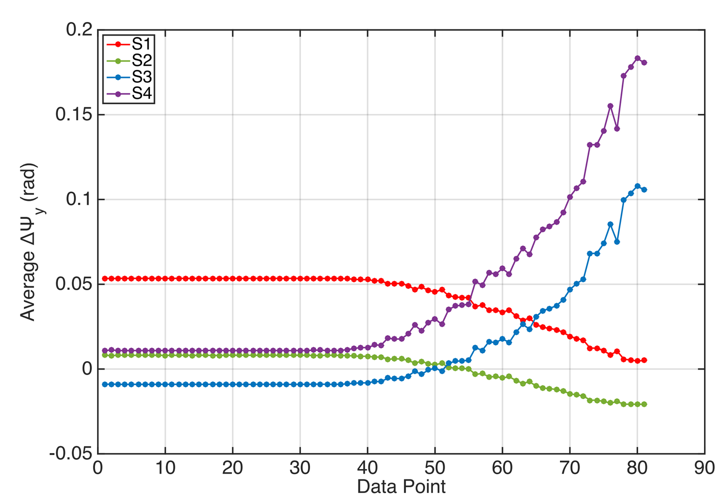

Figure 5: Test case 1: Phase drift + 1 % noise in the first accelerating module.

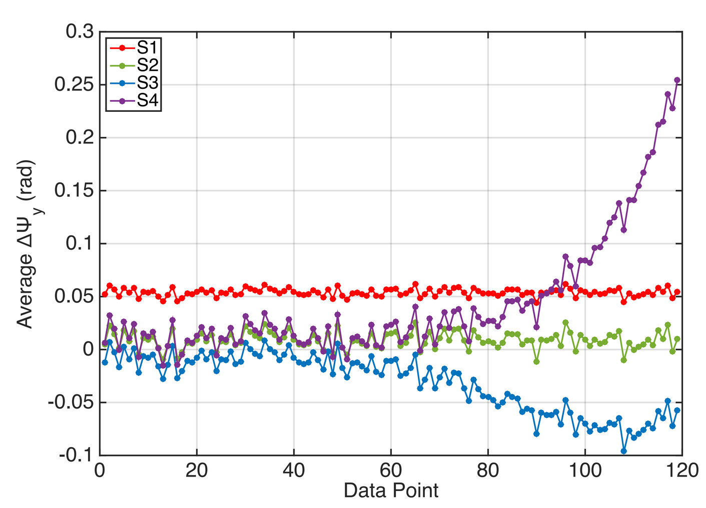

Figure 6: Test case 2: 0.5 % quadrupole k-value noise in S1 + phase drift in second accelerating module.

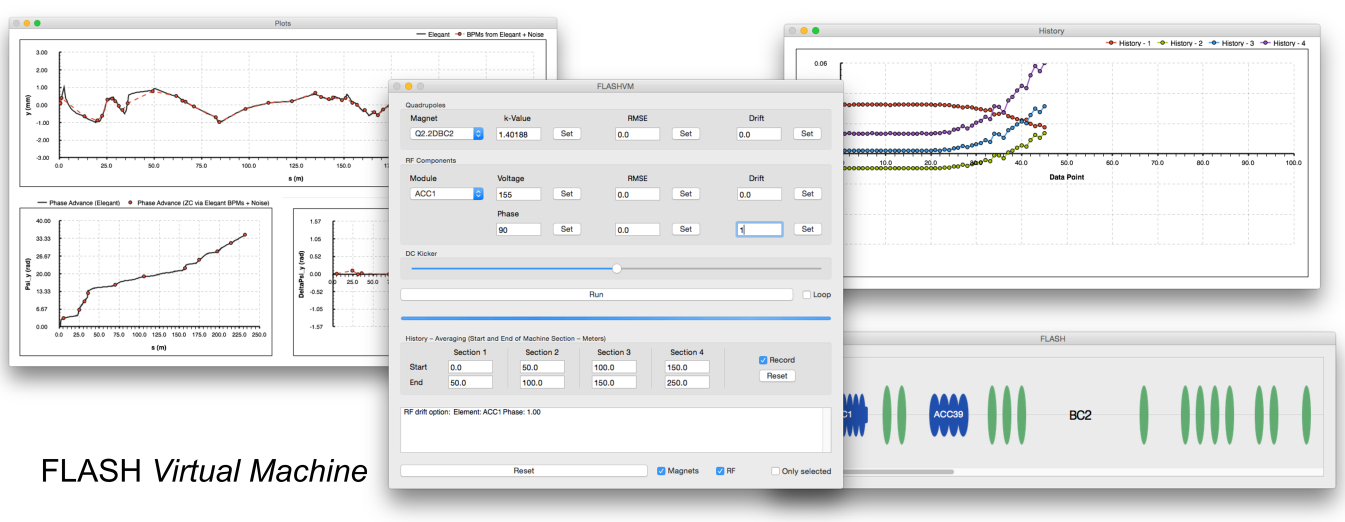

Figure 7: FLASH *Virtual Machine*

Conclusion / Outlook

> Two implementation schemes of the diagnostic pulse method
> Possible implementation at FLASH
> Software implementation (Server/Client)
> Easy to use additional machine stability monitoring tool
> Best case: Non-invasive operation *in the background*
> Even from limited data useful information about the machine stability can be extracted

> Further investigations concerning data analysis (*pattern recognition*) are on-going
> Actual implementation at FLASH planned for the second half of 2015

References

[1] M.Vogt et al., Proc. IPAC 2014, (TUOCA02)
[2] K. Honkavaara et al., Proc. FEL 2013, (WEPSO26)
[3] S. Schreiber et al., Proc. FEL 2012, (MOPD01)
[4] F.Mayet et al., Proc. IPAC 2014, (THPME116)
[5] http://doocs.desy.de
[6] E.Sombrowski et al., "jddd: A Tool for Operators and Experts to design Control System Panels", Proc. ICALEPCS 2013
[7] M. Borland, *elegant: A Flexible SDDS-Compliant Code for Accelerator Simulation*, Advanced Photon Source LS-287, September 2000.

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