Wellcome to the 2nd FLASH2020+ Start to End Simulation Workshop

FLASH2020-

April 20th, 2022







Introduction

FLASH and FLASH2020+

Start-to-end simulations

Review of last workshop

Start-to-end simulations of laser Systems

Synopsis of this workshop

Benchmarking linac simulations

Modifying working points based on our results

EEHG in elegant & Genesis

DESY. | FLASH2020+ 2nd S2E Simulation Workshop | Welcome, Intro, and Review | P. Niknejadi, 20.04.2022

Simulations for accelerating structures and bunch Compressors

- Handshaking between codes and reducing the parameter spaces

The free-electron laser user facility FLASH

SRF linac, two FEL beamlines, 8 experimental stations – 2 accelerator R&D experiments (Xseed & FFWD)





DESY. | FLASH2020+ 2nd S2E Simulation Workshop | Welcome, Intro, and Review | P. Niknejadi, 20.04.2022

315 m

- 7500 h beam operation p.a., 4500 h user exp.
- Superconducting linac @ 1MHz burst
- Intra pulse pattern can be addressed separately for each beamline
- Fixed gap undulators at FLASH1 require dedicated setup and tuning for each wavelength





DESY. | FLASH2020+ 2nd S2E Simulation Workshop | Welcome, Intro, and Review | P. Niknejadi, 20.04.2022

FLASH2020+ project: Seeding in FLASH1

1 MHz coherent pulses in soft-X-ray

Reaching 4 nm seeding with UV seed lasers is possible with Echo Enabled Harmonic Generation (EEHG).

Successful seeding relies on high quality e-beam and seed lasers:

- electron bunch preparation
- R&D for optimal lasers







Fully coherent pulses tens of fs long with variable wavelength (60 – 4 nm) and polarization at high repetition rate.

Tunable seed lasers:

Seed 1: ~343 nm, 100 MW, 500 fs

<u>Seed 2:</u> 297-317 nm, 300 MW, 50 fs

FLASH2020+ Start to End Simulations

Typical approach for modeling a machine as realistically as possible





FLASH2020+ Start to End Simulations and Categories Model the FLASH2020+ as realistically as possible

Bunch Compressors & Accelerating Structures



FLASH2020+ Start to End Simulations and Categories Linacs & Bunch Compressor Systems



Add compression, adjust optics & Track in Elegant

Start with an oncrest file & design optics File in MAD

Impact-Z

Model beam realistically from the Gun

SelaV

- **Resources:** Mainly Maxwell (CPU)
- **Codes:** elegant, impact-Z, SelaV
- **Results from last workshop:** Optimization & WP Studies



Impact-Z results from last workshop: Optimization & WP Studies (M. Dohlus)

impact-Z (approach)

- No gun simulation: Artificial Gaussian distribution \bullet
 - Space charge matching to prevent any issues with the beta functions \bullet
 - Introduce some nonlinear terms in the initial distribution to be able to optimize and prevent emittance growth in the first cavity

Complicated optimization

- space charge matching
 - Could need up to 50 runs
 - Need to be performed with lower number of particles

Start with design energy profile — adjust working point — cavity phasing and RF compression

Impact-Z results from last workshop: Optimization & WP Studies (M. Dohlus)

impact-Z (FLASH2020+ results)

- Normal Conducting Gun, 400 pC, from 31A to 500 A (Compression factor of 16 (4x4)) @ 1350 MeV \bullet CSR included, Intra beam scattering is not included (needs an advanced model from the beginning) \bullet Compression of 3 different cases (250, 25, and 4 electron per macro-particle) \bullet
- - Conclusion and Next steps
 - Currently it's possible to run with 64 processors- simulations take about 1-2 days This working point is somewhat aggressive: best to have lower initial current but higher
 - compression
 - Gun + Laser heater simulations with 1-2 electron per macro particles

Impact-Z results from last workshop: FLASH2020+ beam after BC2 (M. Dohlus)





250 e/m

25 e/m

DESY. | FLASH2020+ 2nd S2E Simulation Workshop | Welcome, Intro, and Review | P. Niknejadi, 20.04.2022

shapes of modulations also change and suggest significant nonlinear effects

Precise calculation with 1-2 electron per macro-particles is needed





Intro to SelaV and elegant results from last workshop: Optimization & WP Studies (P. Amstutz & D. Samoilenko)

SelaV (intro)

- Solve the Vlasov equation numerically and find a solution for the phase space density (PSD) \bullet
 - Numerically stable method: store PSD values on a grid (inside the bounded rectangles) \bullet
 - Back-track PS coordinates and interpolate old PSD then update
 - Increase resolution by tree-based domain decomposition
- It has 2 Parts: libselav and selav1d (built on libselav) \bullet
- Allows for implementing additional features in the future and as needed \bullet

Elegant

- Uses effective impedance (simplified model) \bullet
- Used for initial study of Laser Heater reducing the beam quality in the beginning is beneficial
 - Next step: Benchmark impact-Z, SelaV, and Elegant for one working point (NEXT TALK)

Start from a less aggressive working point





FLASH2020+ Start to End Simulations and Categories Model the FLASH2020+ as realistically as possible



Resources: Mainly Maxwell (GPU) **Codes:** Chi3D (similar to a Matlab toolbox) **Results from last workshop:** Full S2E simulations for the whole system

Chi3D results from last workshop: FLASH2020+ S2E simulations for laser system (T. Lang)

3+1 dimensional simulation building blocks (chi3D)





FLASH2020+ Start to End Simulations and Categories Model the FLASH2020+ as realistically as possible



Resources: Maxwell and JUWELS (several million cpu-hs) **Codes:** Elegant, Genesis, & Puffin **Results from last workshop: Optimization runs for different** working points: electron beam energy, resonant wavelength, jitter, ...

Pseudo-one4one approach



Next steps:

Put together the first Pseudo-S2E results with the old working point, artificial beam, and pseudo-one4one approach for MAC

- Resolve and Debug any issues remaining \bullet
- Benchmark simulations in the Seed and Radiator sections \bullet
- Improve handshaking \bullet

Gun simulations similar to XFEL

Using Astra and 5E8-1E9 particles but in multiple runs (using linearity and superposition principle) \bullet **CASE** studies with full one4one simulations **S2E studies with the Final Framework**

Reduce the parameter space through additional studies and optimizations (THIS AFTERNOON'S TALKS)

Today's Agenda

Status of Electron Beam Transport Studies in Elegant, SelaV and Impact-Z (Joint Talk) <u>P. Amstutz</u>

Break until 13:00

bunching level

<u>F. Pannek</u>

Study of CSR in EEHG chicanes with elegant and Genesis

D. Samoilenko

DESY. | FLASH2020+ 2nd S2E Simulation Workshop | Welcome, Intro, and Review | P. Niknejadi, 20.04.2022

Exploring EEHG working points and their response to seed power jitter while actively conserving

Feedback & Questions?



Thank you