Femtosecond Resolved Determination of Electron Beam and XUV Seed Pulse Temporal Overlap in sFLASH

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Roxana Tarkeshian
University of Hamburg

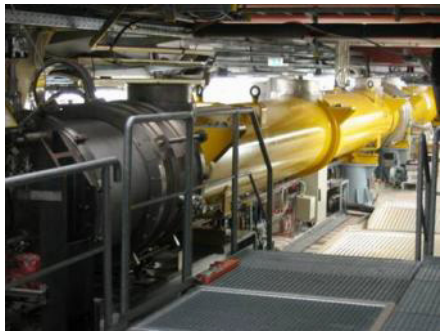
Outline

- FLASH upgrade & seeding FEL in Hamburg
- The concept, experimental setup & synchronization for longitudinal overlap determination
- Statistical analysis & tolerance study on the timing jitter
- Experimental results
- Summary and outlook

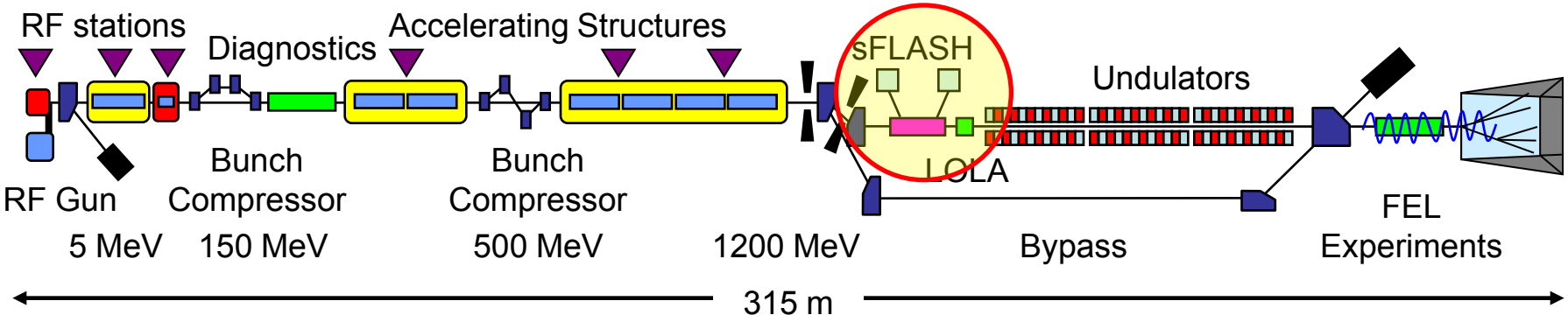
Free electron LASer in Hamburg (FLASH)

> TESLA type superconducting accelerating modules

3.9 GHz module



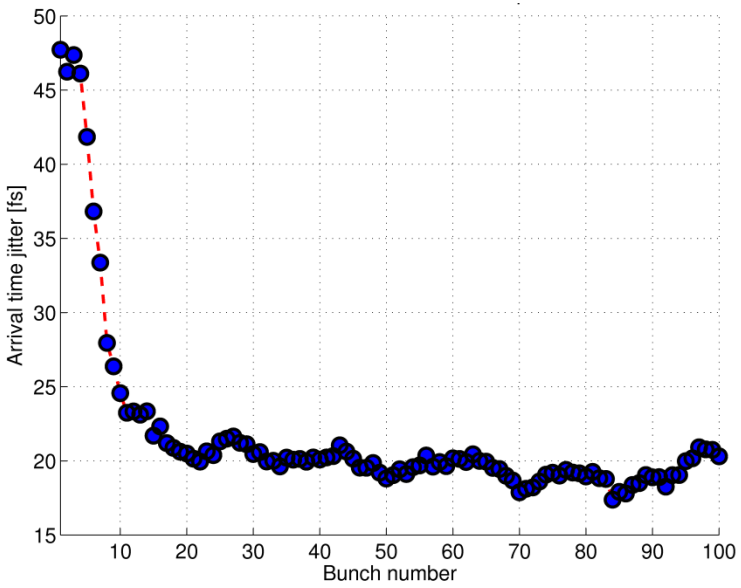
sFLASH

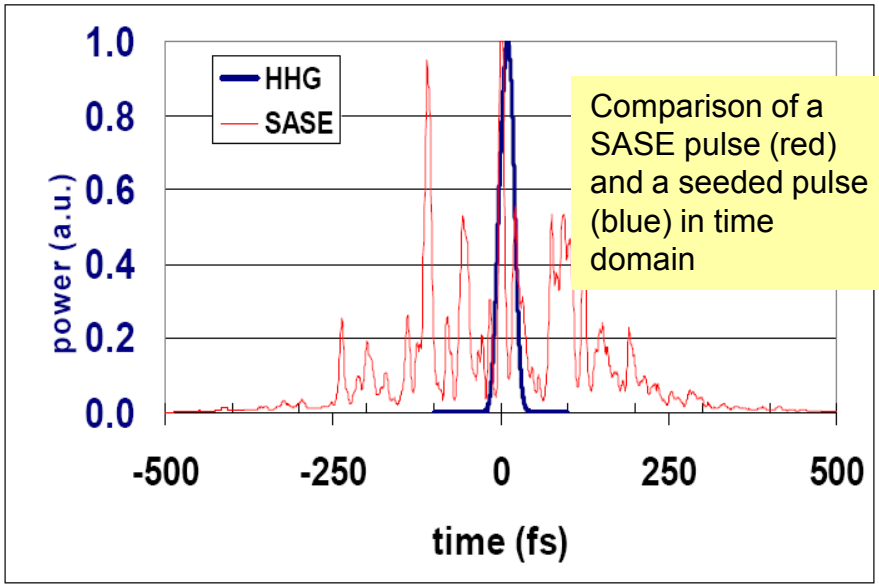


Experimental Hall

Motivation

- Demonstration of direct seeding with high harmonics (HHG) at wavelength below 40 nm
- Temporal stability for pump-probe experiments better than 10 fs
- Improve the longitudinal coherence of the FEL in comparison to SASE radiation





Comparison of a SASE pulse (red) and a seeded pulse (blue) in time domain

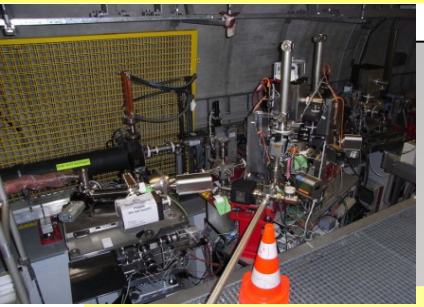
sFLASH Installation

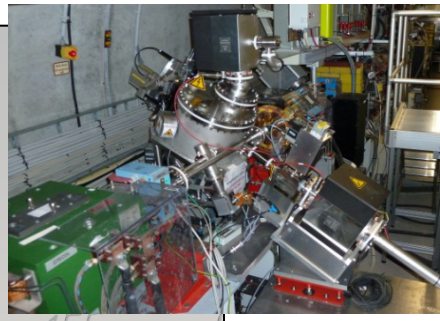
hutch for first experiments with sFLASH pulses

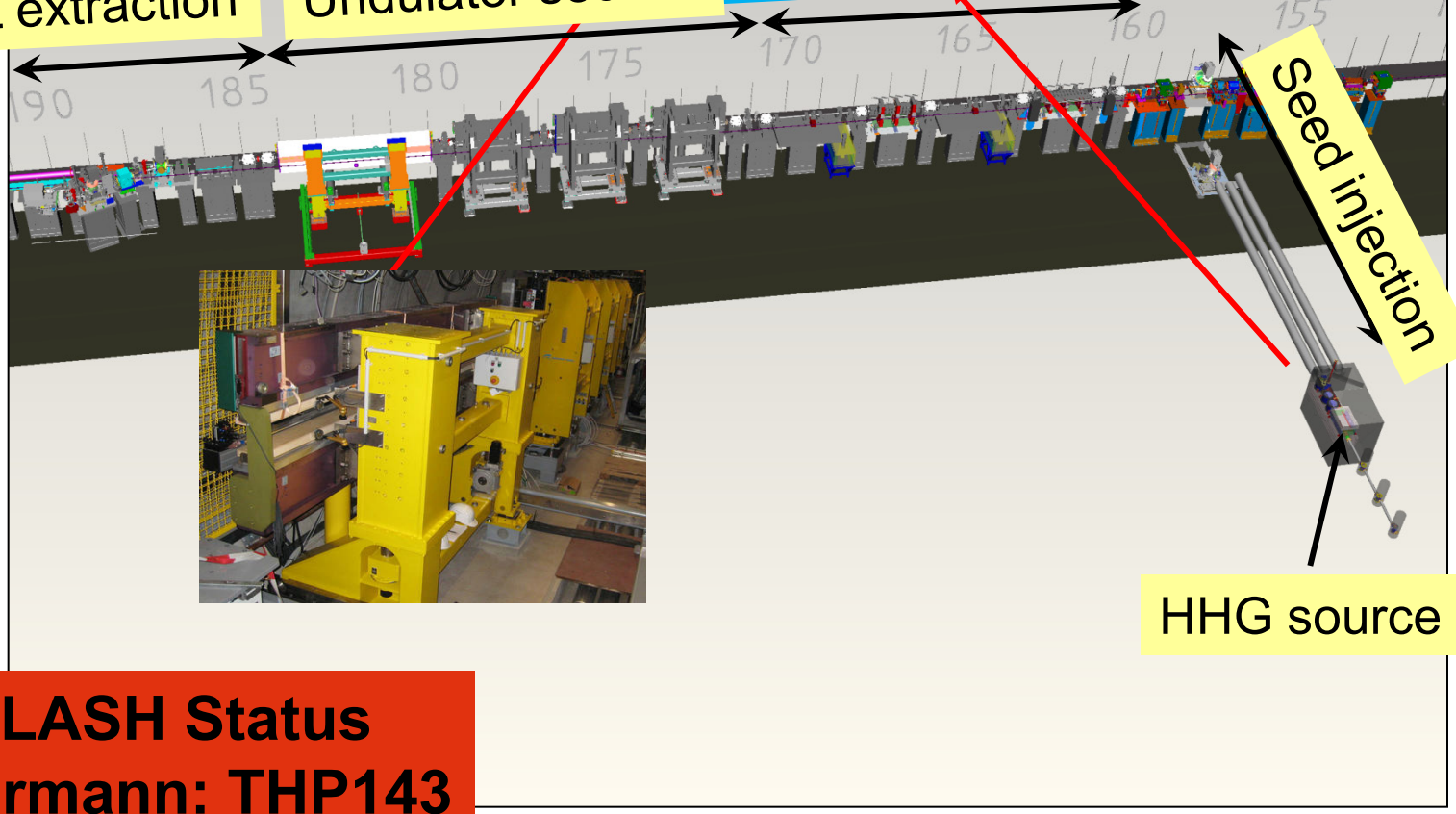
Ti:Sa laser system and HHG source

sFLASH Status
T.Laarmann: THP143

sFLASH Installation





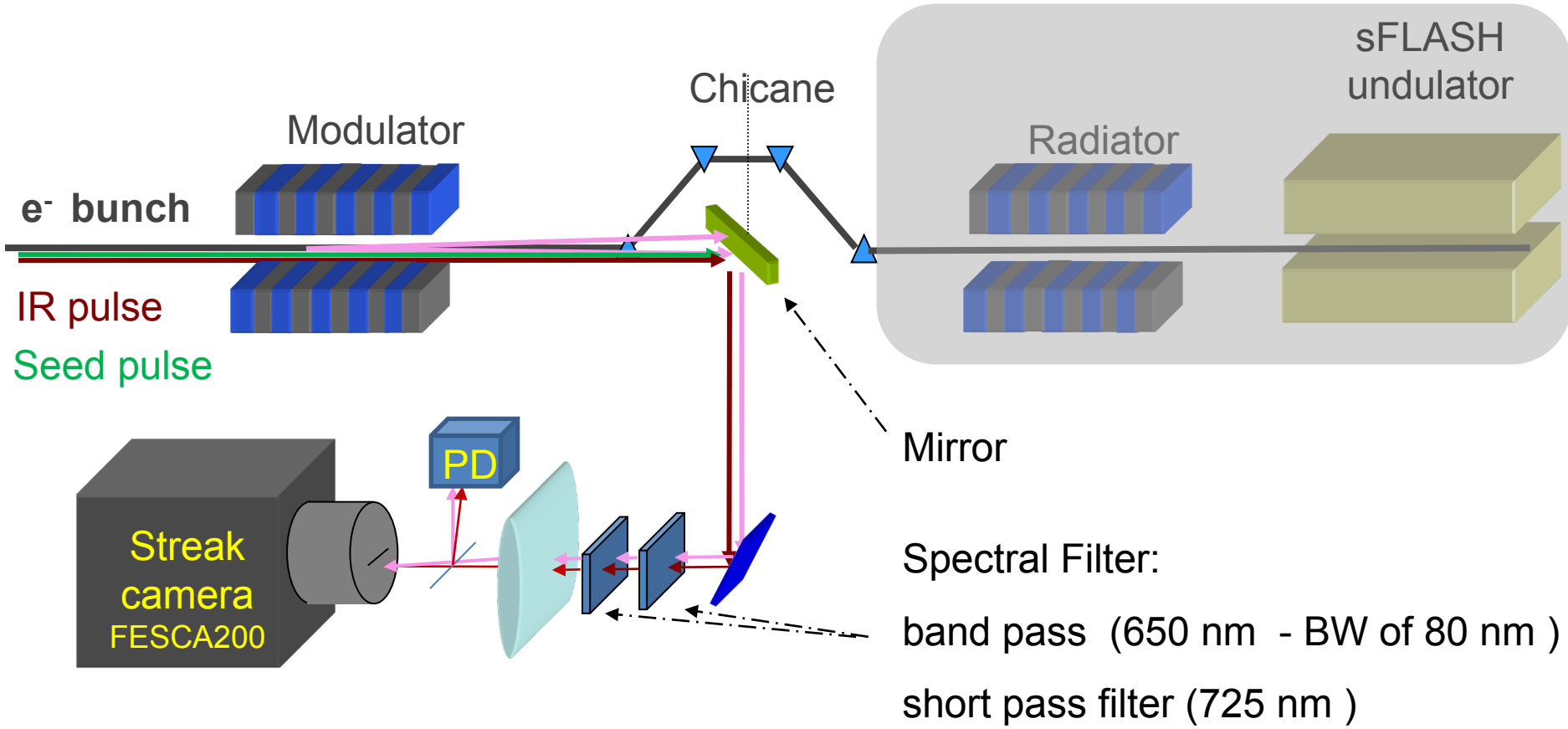


sFLASH Status
T.Laarmann: THP143

Coarse temporal overlap measurement

Pulses used for the temporal overlap with picosecond resolution:

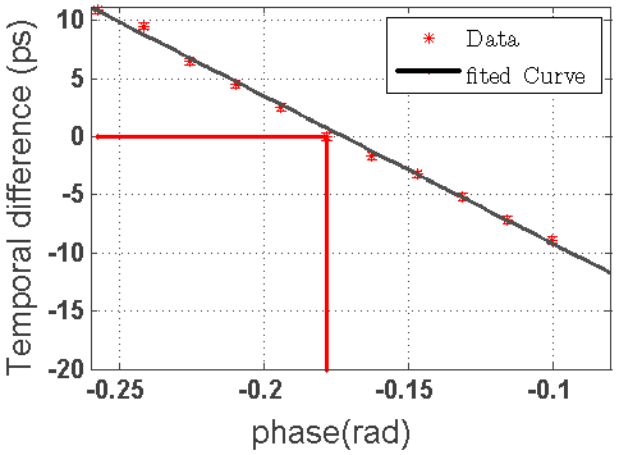
- Synchrotron light of modulator
- IR laser (which co-propagate with the seed pulse)

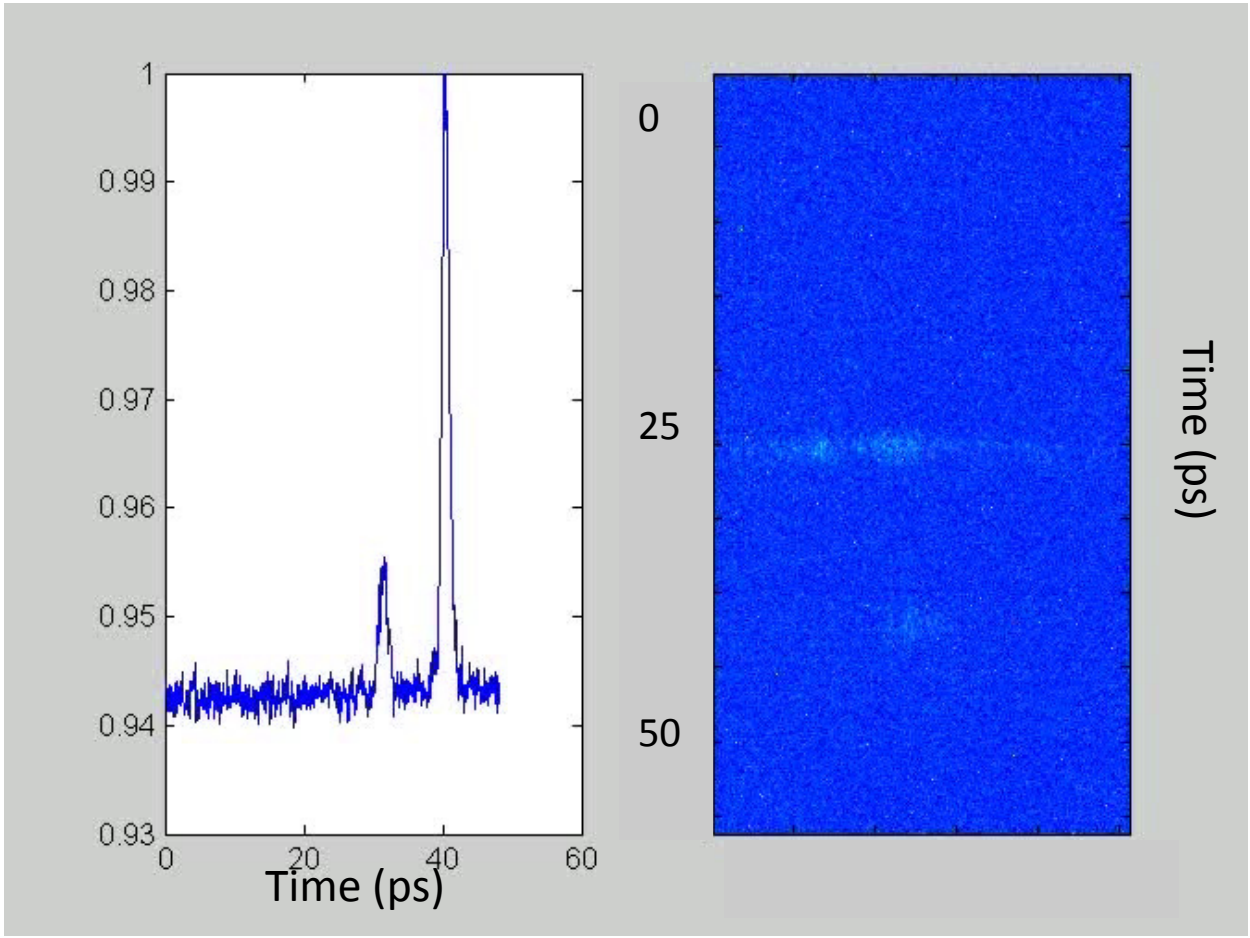


Coarse longitudinal scan

Streak camera based temporal overlap:

Scan range: 10 ps,
Steps: 1 ps,
Resolution : ~ 0.35ps





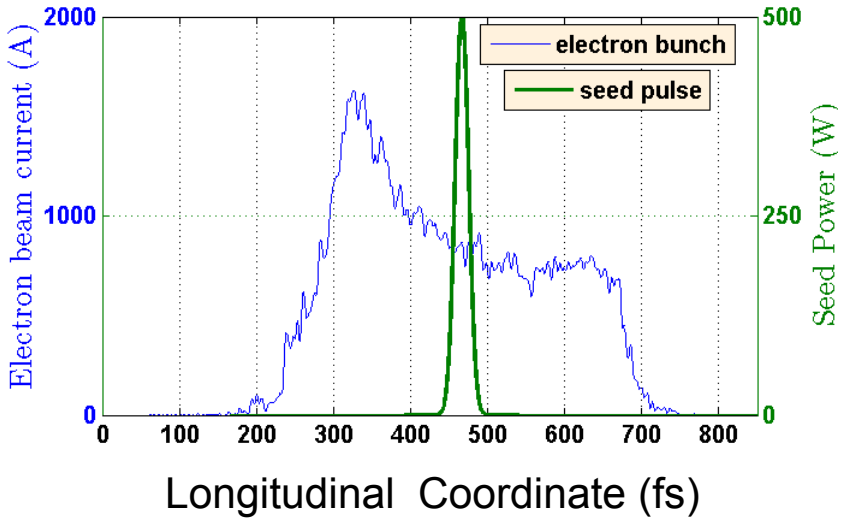
Why do we need better resolution?

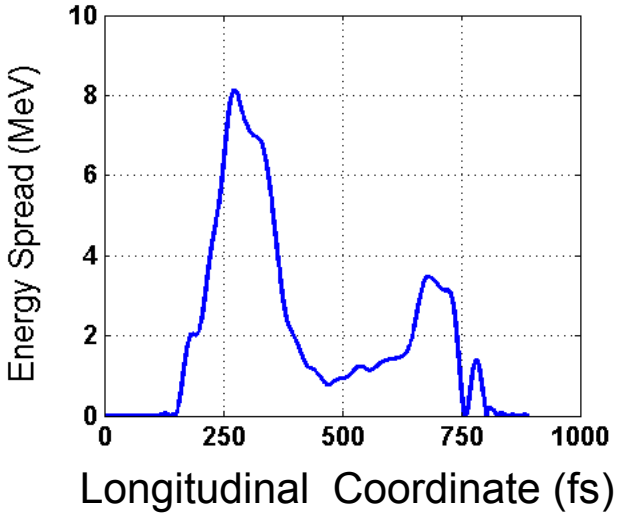
Tolerances of relative timing jitter

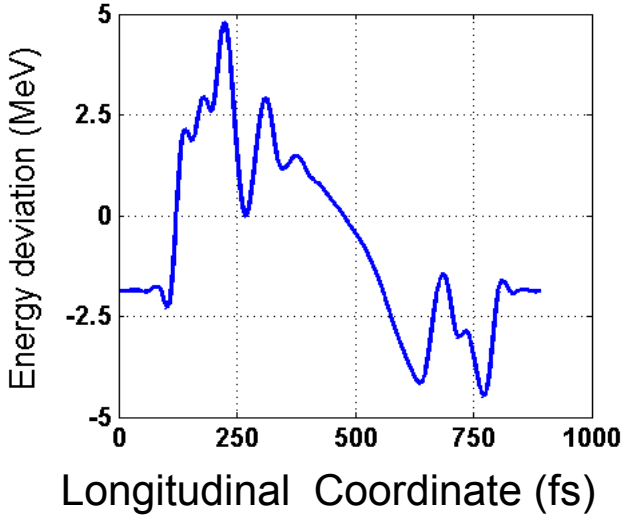
Beam parameters used for the simulation through the **sFLASH** undulator

- Measured electron bunch distribution
  Peak Current :1.5 kA
  Pulse length: ~120 fs (RMS)

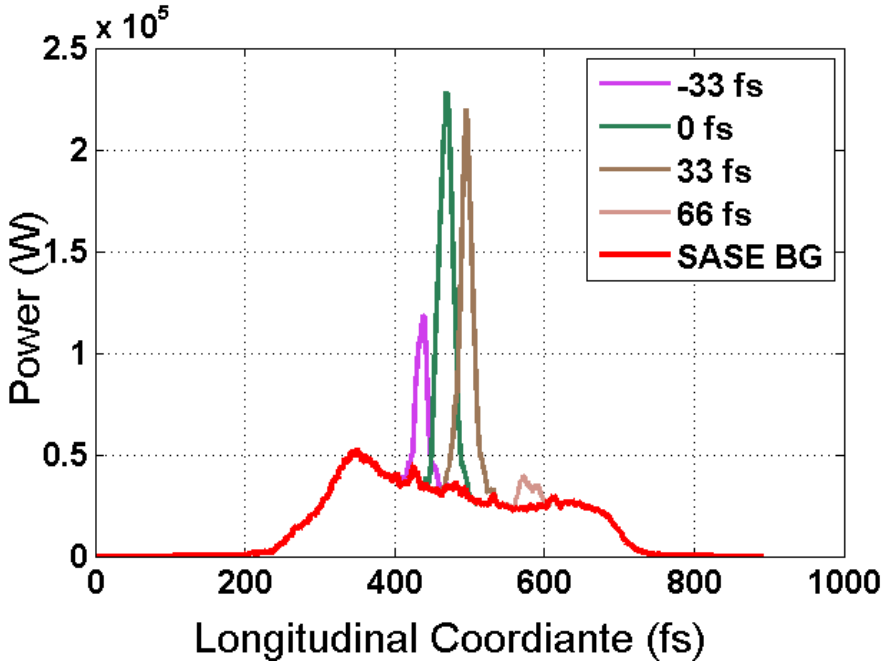
- Seed laser
  Energy of source: 2 nJ @38nm
  Coupled energy: >10 pJ
  Pulse duration: 20 fs FWHM







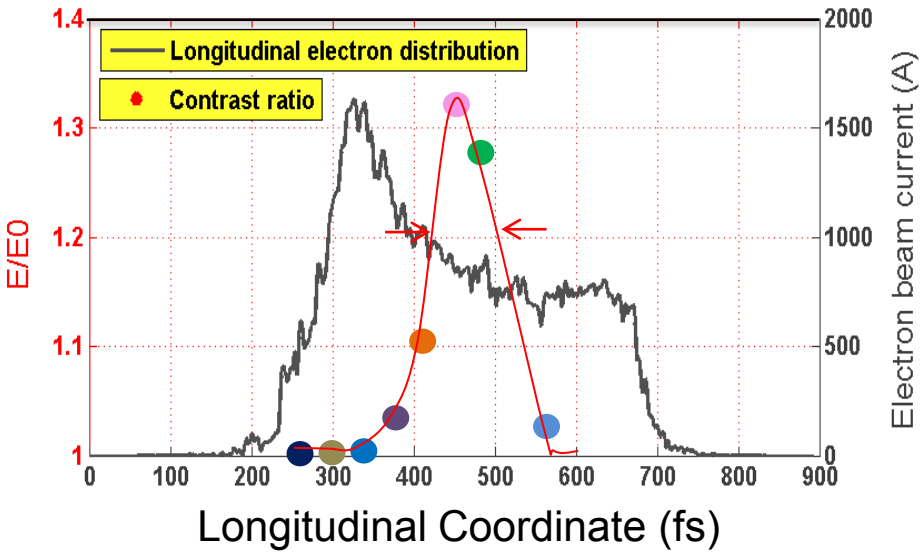
Simulation result using GENESIS (1)



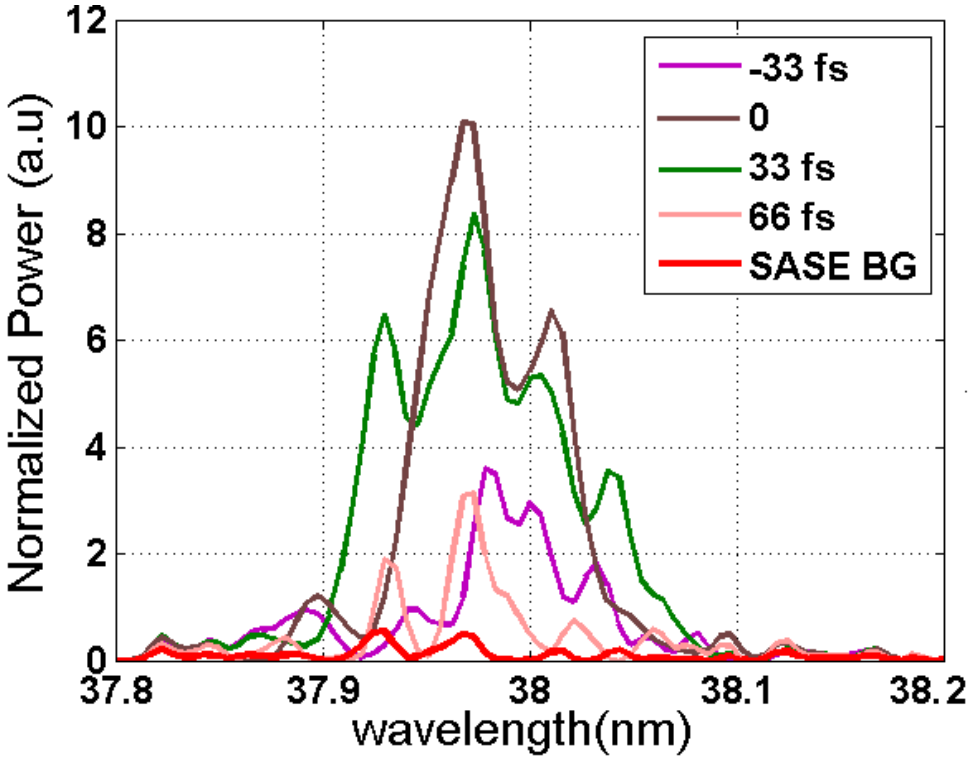
Point wise simulation of seed pulse along electron bunch.
The max enhancement is achieved not at the peak current.

- Energy contrast ratio E_{seeded}/E_{SASE} for different seed pulse positions within electron bunch

→ Gain region only ~45fs RMS long



Simulation Result (2)

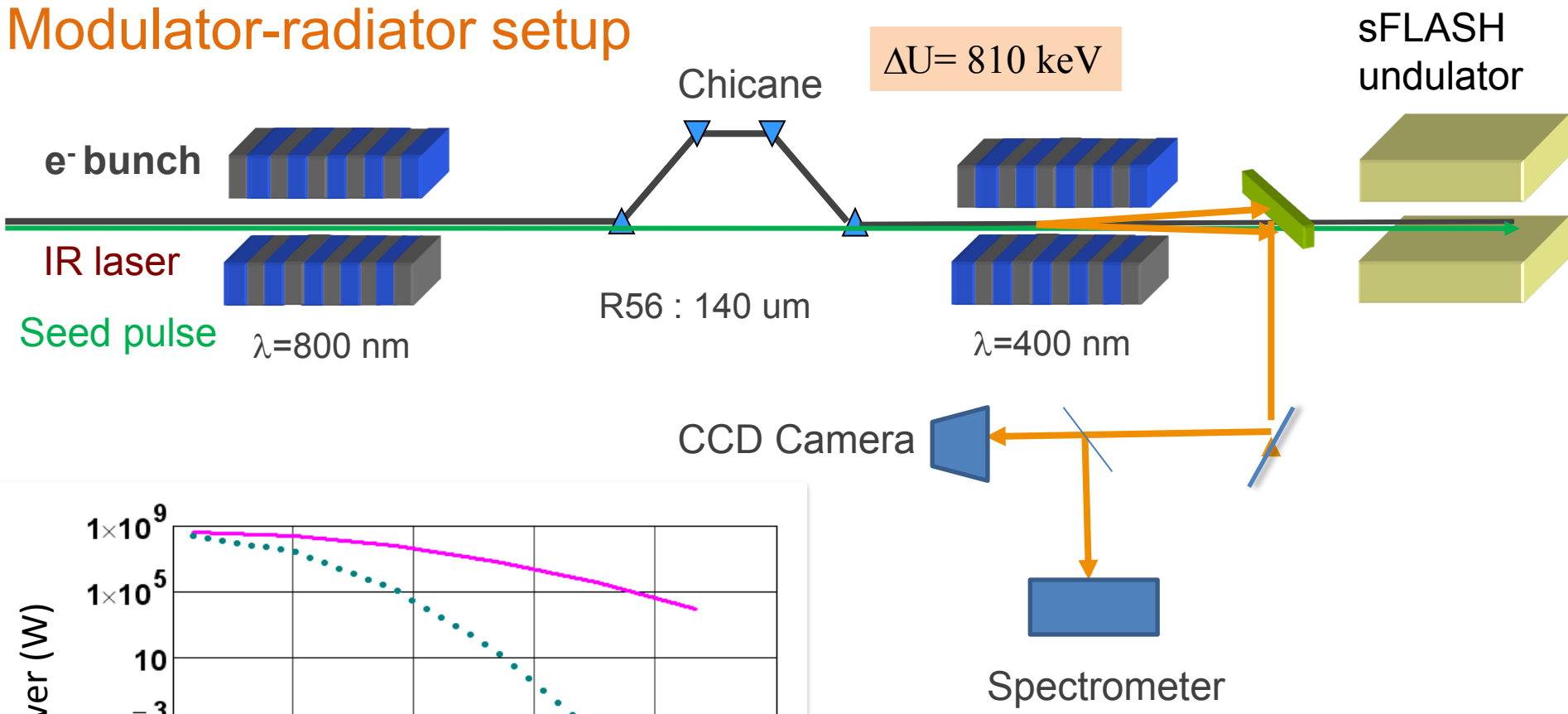


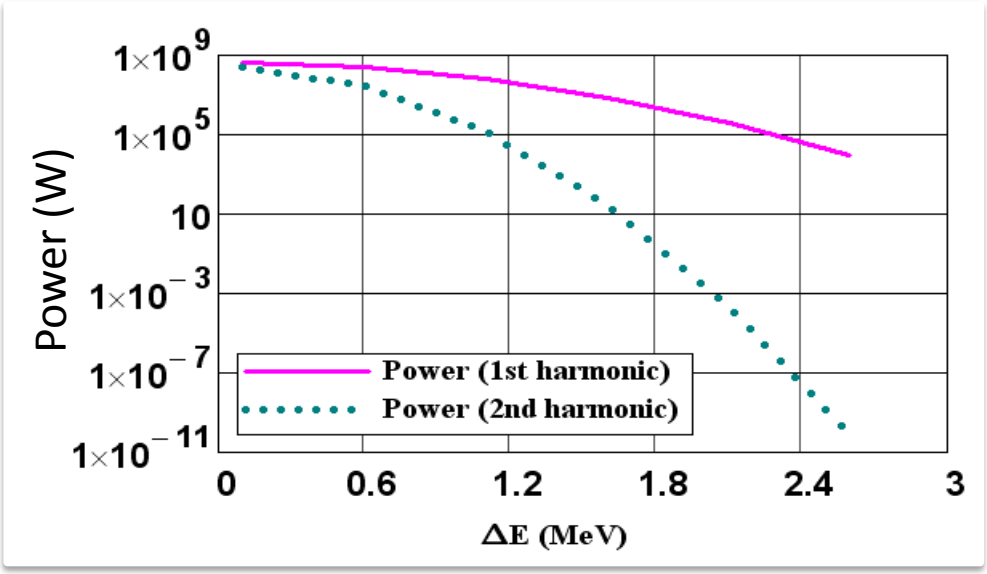
- Power of the seeded pulse normalized to the SASE background maximum,
- In the short bandwidth around the resonance wavelength enhancement in the power by a factor of 10 is observable.

The temporal overlap with resolution better than 100 fs is needed.

Fine temporal overlap with femtosecond resolution

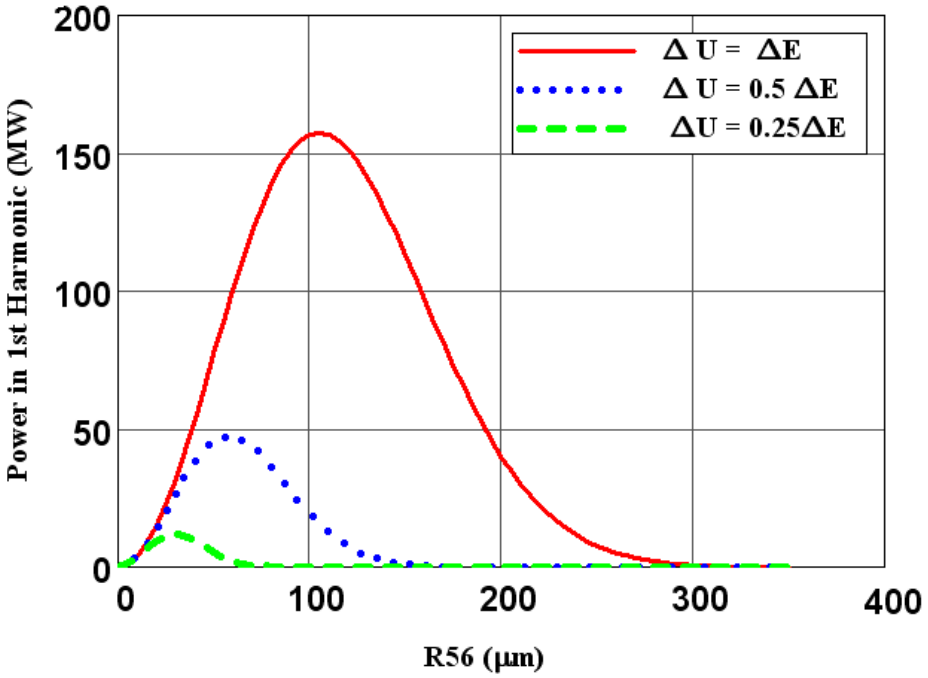
Modulator-radiator setup

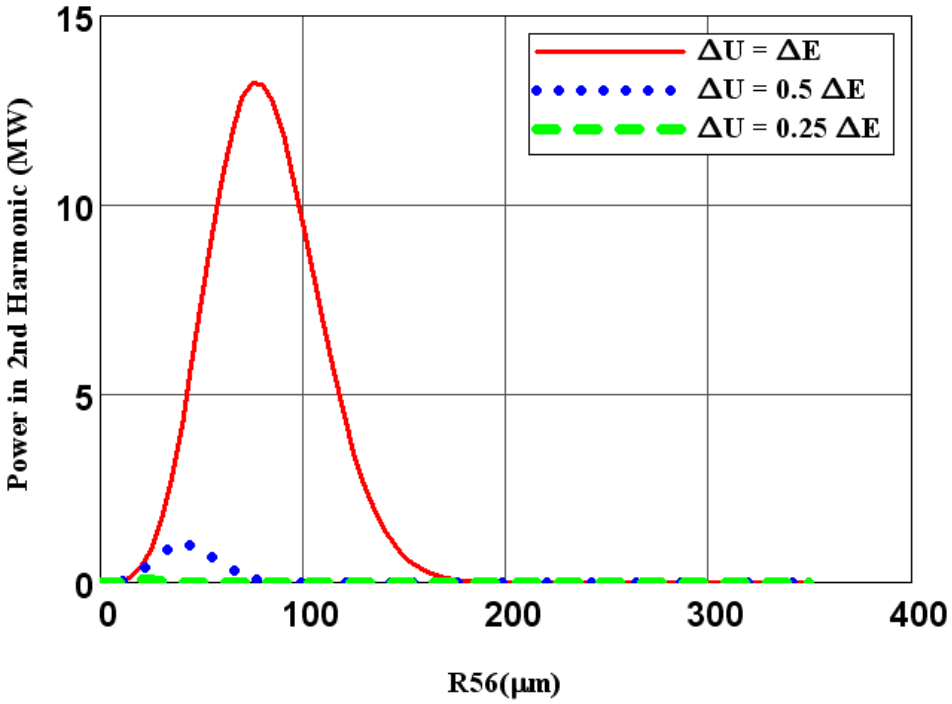




Using coherent light which imprints in enhanced light on detector

Analytical approach



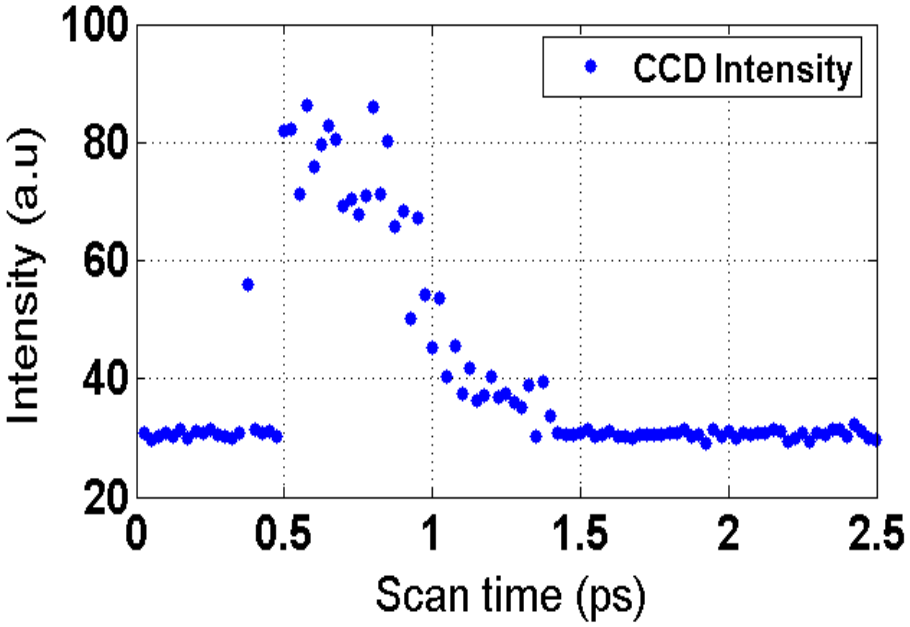


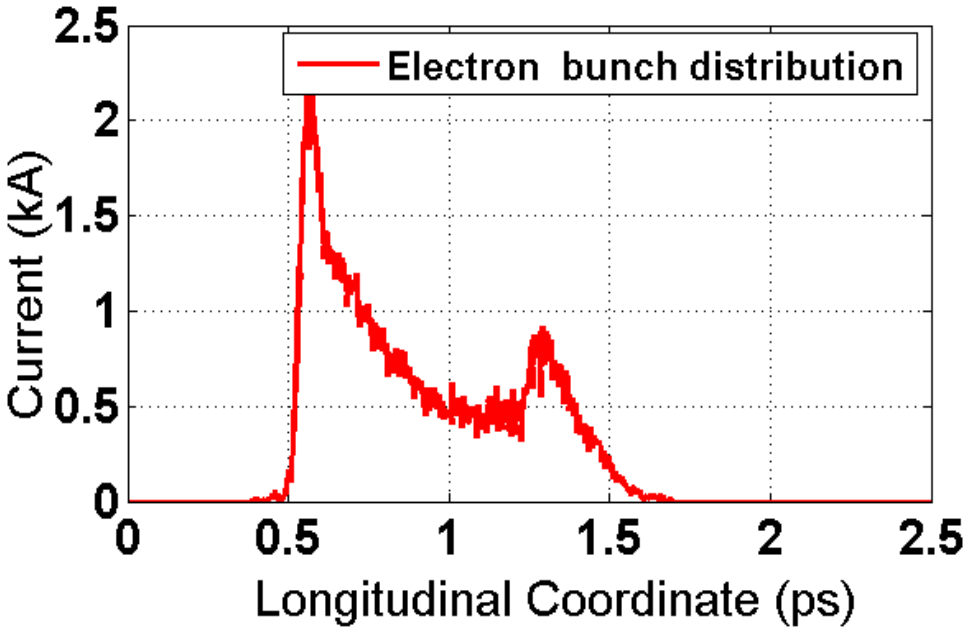
Enhanced coherent power in the 1st Harmonic of radiator

Enhanced coherent Power in the 2nd Harmonic of radiator

Overlap with femtosecond precision

Scan range: 1ps, Step: 25 fs, Average over: 20 pulses





The longitudinal overlap of two pulses imprints in the enhanced intensity of the standard CCD camera and shows a replica of longitudinal electron bunch distribution.

Summary & outlook

- Nanosecond temporal overlap of electron beam and seed drive lase using fast photo detectors
- Picosecond temporal overlap of pulses using streak camera based approach
- Using coherent undulator radiation for the temporal overlap determination with sub picosecond resolution

Next Step:

- Using RF based streak camera for better synchronization to master oscillator
- Optical synchronization of IR laser oscillator

Thanks to sFLASH team

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