An overview of FEL seeding methods

And their possible application in THz for PITZ

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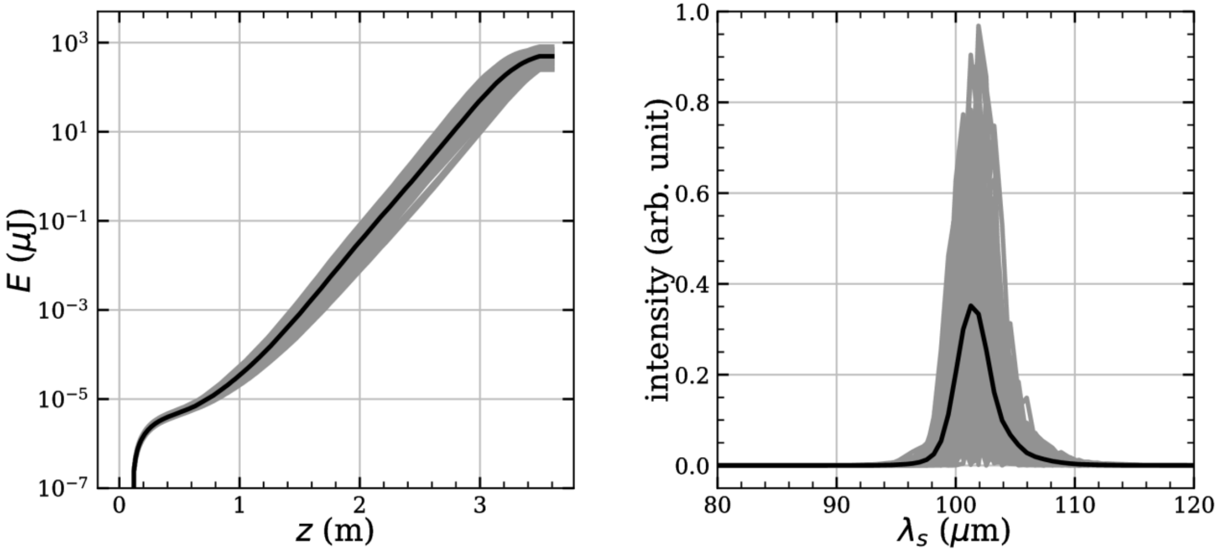
Overview of talk

Introduction

Meeting the spectral and CEP stability requirements

- SASE
  - No seeding
  - Noise in beam signal, stochastic
  - Time and spectral jitter
  - Shorter coherence length
- Seeded FEL
  - Introduce signal at resonant frequency
  - The FEL amplifies the signal
  - Coherent signal – coherent output

Pulse energy growth along undulator and final THz spectrum for 100 pulses and their average (sim., courtesy X.K. Li @ PITZ)

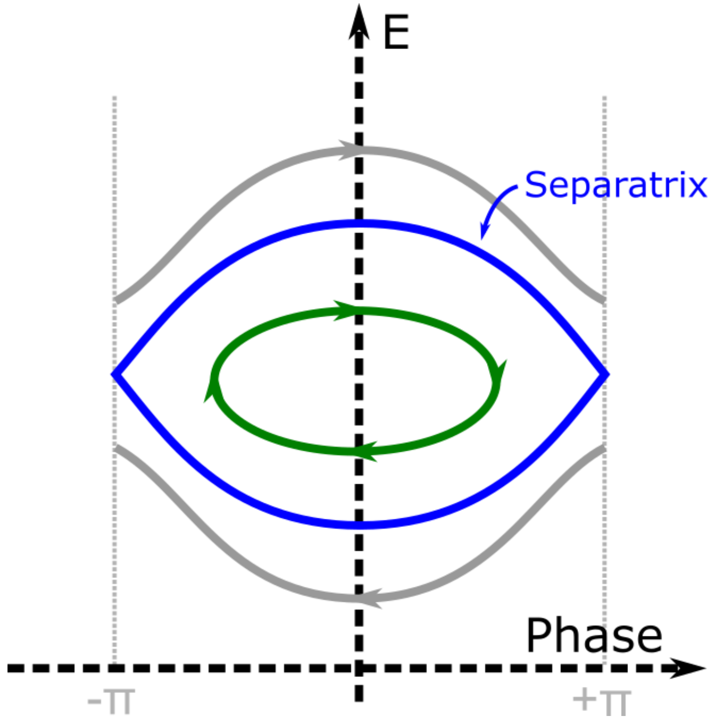


External laser pulse

Microbunching driven by external field

- Microbunching
  - Energy to density modulation in FEL bucket
  - FEL bucket - undulator and radiation fields
- External field at resonant frequency
  - Initial FEL bucket, jump-start microbunching
  - Field properties inherited in FEL output
- External laser pulse – coherent seeding
- Application in THz range
  - Power-limited sources (low rep. rate)
  - Difference-frequency generation
  - Parametric amplification
  - Other indirect methods

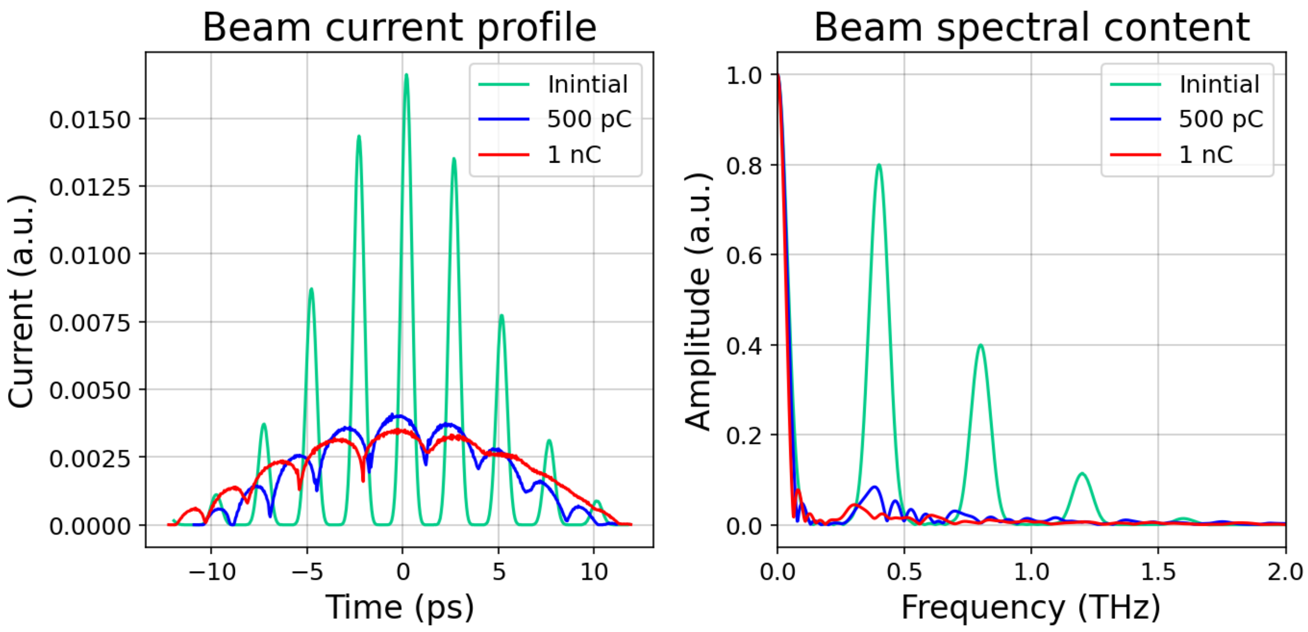
$$\theta = (k_{und} + k_{rad})z + \omega_{rad}t$$



Pre-bunched beam

Beam current modulation

- Beam current modulation at resonance
  - Microbunching in advance
- Methods
  - Photocathode laser modulation
  - Mask in dispersive section
  - Wakefields – dielectric lined waveguide
  - Exchanging transverse-longitudinal coordinates
  - Gridded gun, triode
  - Inverse-FEL
    - Laser seed pulse is absorbed
- For THz at PITZ
  - Direct: photocathode laser, mask in BC
  - E-modulation to ballistic bunching: DLW



FEL oscillator

Low-gain FEL

- FEL oscillator – undulator in mirror cavity
  - FEL output acts as seed pulse
- Multiple pass device
  - Saturation after many bunches
  - Equilibrium state, mode-locking
  - CEP stable and defined
- For THz and at PITZ
  - Mirror properties for THz (reflectivity, shape, etc.)
  - Side beamline next to the high-power FEL at PITZ

SASE re-amplification

Two stage FEL

- SASE FEL pulse (first undulator)
  - Spectral and time jitter
  - Narrow bandpass filter
- Seeded FEL (second undulator)
  - Filtered SASE pulse as seed
  - Narrow bandwidth
- For THz at PITZ
  - Technically complicated and less affordable
  - Time jitter could remain
  - Bunching after first undulator

Superradiant FEL

Coherent synchrotron radiation (CSR) emission

- Very short bunch in undulator – CSR
- Well defined, CEP stable
- Disadvantages
  - Difficult creation and transport
  - Lower beam charge and output power
  - Broad spectrum – requires filtering
- Zero-slippage
  - Curved parallel plate waveguide in undulator
  - Short FEL pulse
- Afterburner – reuses X-ray FEL short bunch
- Alternative mode for PITZ, reuses components

Advanced SASE schemes

Artificially increased slippage in FEL

Improving of the temporal coherence of SASE

- Slippage between radiation and bunch in FEL
- High-brightness SASE (HB-SASE)
  - Periodically delayed bunch wrt radiation
  - Chicanes between undulators of sectional FEL
- Improved SASE (iSASE)
  - Delay close to the cooperation length
  - Chicanes between undulators of sectional FEL
- Purified SASE (p-SASE)
  - Reduced radiation bandwidth
  - Sub-harmonic undulator in exponential section

- For THz at PITZ
  - Technically complicated and less affordable
  - To be considered for future use

Summary

- Multiple options to improve coherence over SASE
- Introduction of initial signal
- Alternatives to high-gain FEL
- Improving the SASE conecept

Summary

- Multiple options to improve coherence over SASE
- Introduction of initial signal
- Alternatives to high-gain FEL
- Improving the SASE concept

THANK YOU

Sources

Unsorted

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