Simulations of temporally modulated ellipsoidal electron bunches

Study of possible THz seeding option

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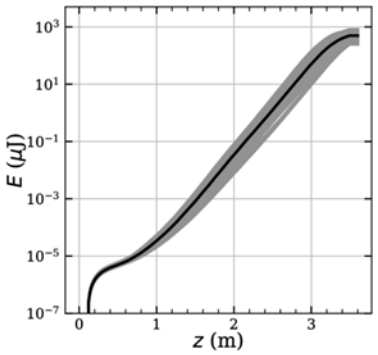
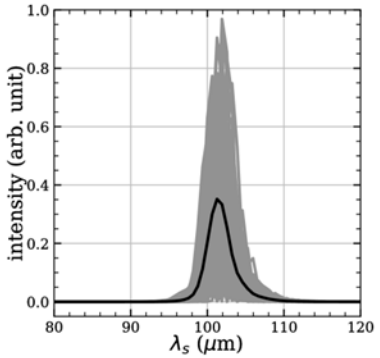
Zeuthen, 14.11.2019

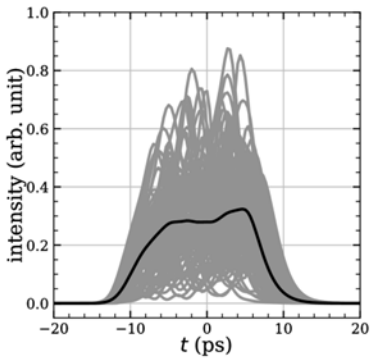
Introduction

Pre-bunching to improve CEP stability of SASE → "Seeding"

Start-to-end simulation with flattop laser (X.-K. Li)





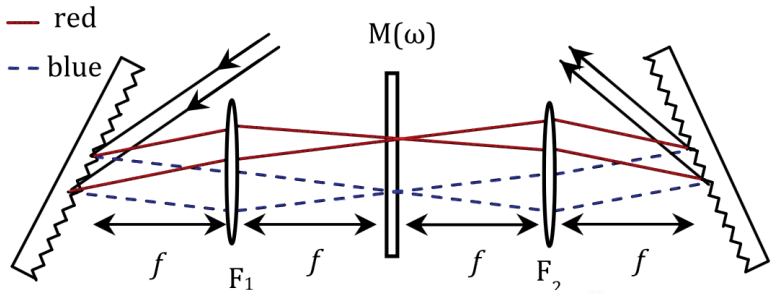


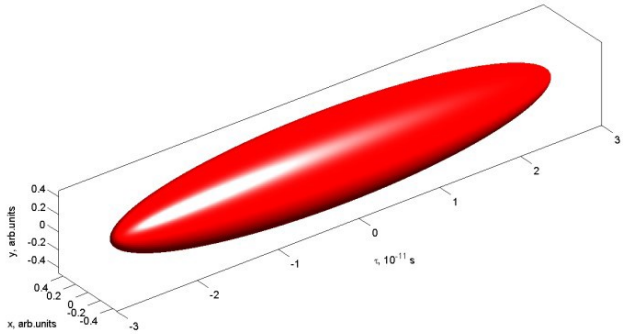
Parameter	Value	Unit
Pulse energy	**493.1±108.8**	μJ
Peak power	52.7±11.8	MW
Centre wavelength	**101.8±0.7**	μm
Spectrum width	2.0±0.4	μm
Arrival time jitter	1.45	ps

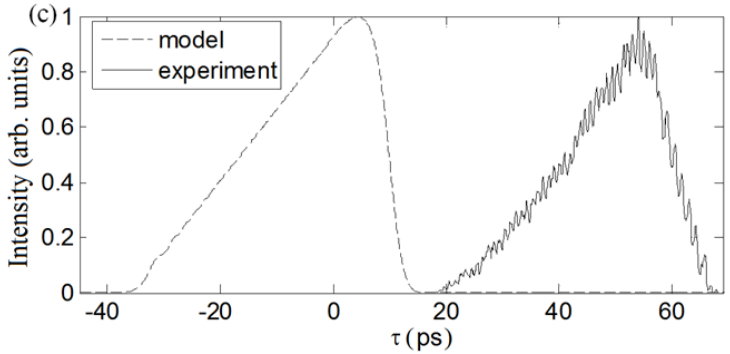
- **Photocathode laser pulse temporal modulation**
- Using IR laser, modulator and BC for E or δE modulations
- Using CDR from short seeding bunch
- Using corrugated structures
- Using Dielectric Lined Waveguides - DLW (first experiments)

Modulated 3D ellipsoidal laser pulses

Proposal from IAP

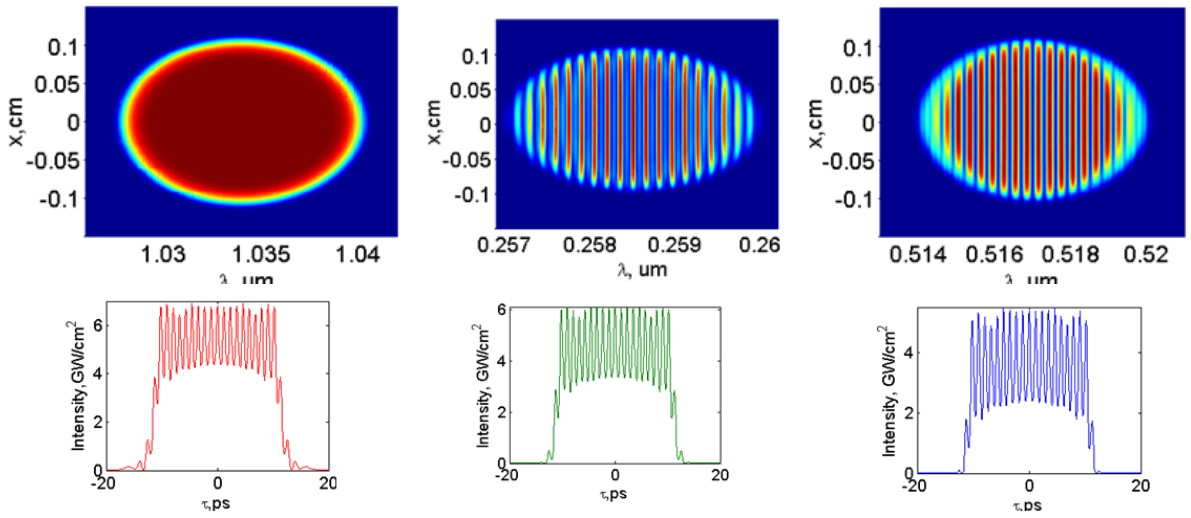






$$|E(\tau)|^2 = \frac{8\pi\Delta\omega^2}{\sqrt{a^2+b^2}} e^{-\frac{2\tau^2 a}{a^2+b^2}} \{1 + 2B\,\mathrm{ch}[\rho\tau]\cos[\mu]\cos[T_I\tau] + 2B\,\mathrm{sh}[\rho\tau]\sin[\mu]\sin[T_I\tau] + B^2/2 \cdot (\mathrm{ch}[2\rho\tau] + \cos[2T_I\tau])\}$$

$\mu = \frac{T^2 b}{a^2+b^2}$ total phase, that define modulation depth



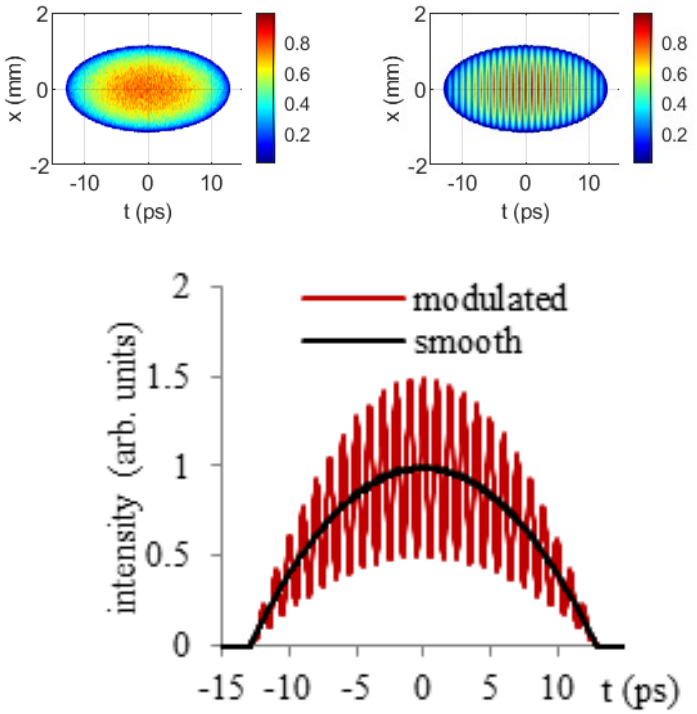
I.V. Kuzmin, "Generation of ellipsoidal laser pulses with periodic intensity modulation", talk at PITZ Collaboration meeting", November 2019

I.V. Kuzmin, S.Yu. Mironov, E.I. Gacheva, A.K. Potemkin, E.A. Khazanov, M.A. Krasilnikov, F. Stephan, **"Shaping picosecond ellipsoidal laser pulses with periodic intensity modulation for electron photo injectors",** paper submitted to Applied Optics Journal in November, 2019.

Electron bunch generation at PITZ

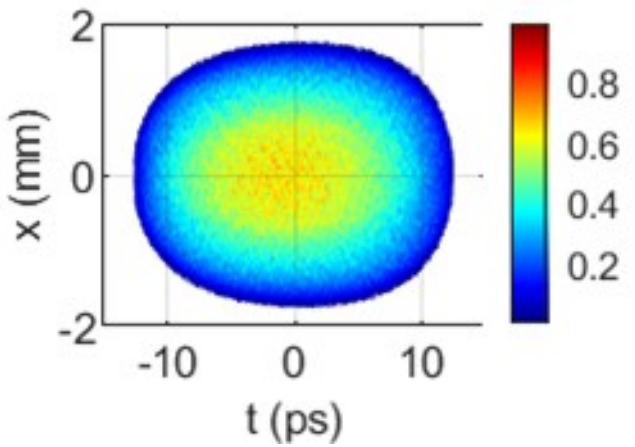
Input for ASTRA simulations

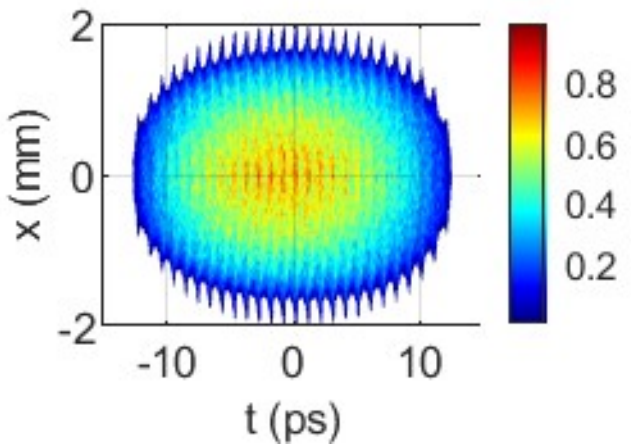
- Ecath(Gun4.6)=60.58MV/m, MMMG (not optimized*)
- Photocathode laser:
  - 20ps FWHM 3D ellipsoid
  - XYrms=0.5mm (not optimized)
  - Smooth profile vs. modulated 1ps period with 50% in intensity
- Q=0.5nC (not optimized)
- MaxB=-0.22643
- Booster: Emax=18.3MV/m, MMMG (not optimized*)
- Monitor at z=5.27m
- ASTRA:
  - 1M macroparticles
  - Nlong_in = 200
  - with and w/o NR

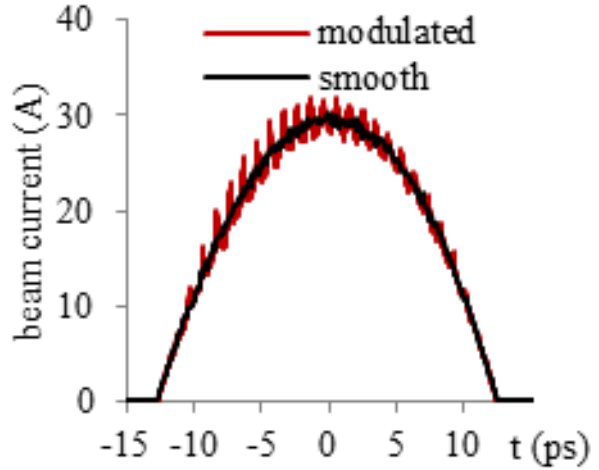


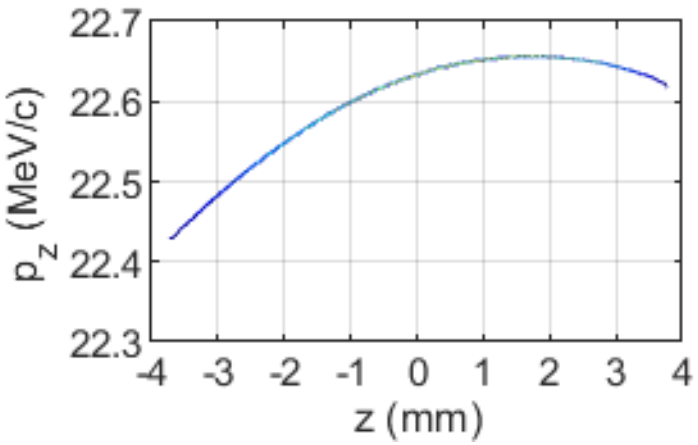
Electron bunch generation at PITZ

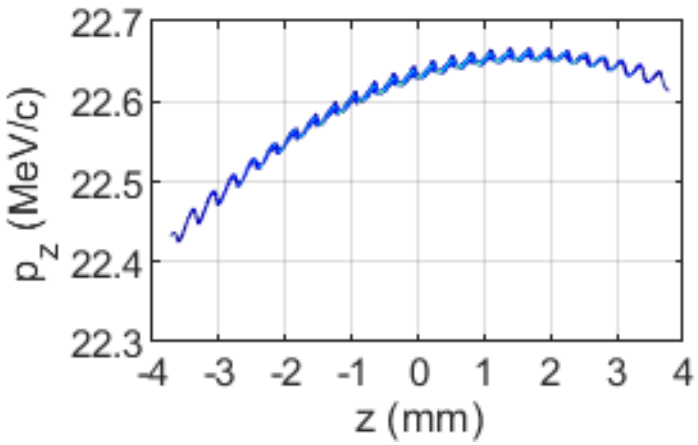
Results of ASTRA simulations (z=5.27m)

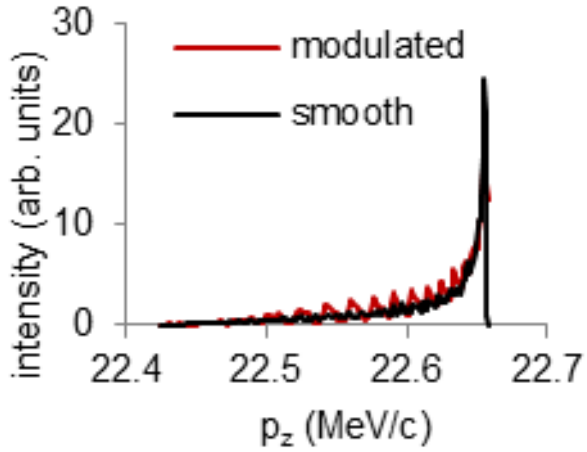






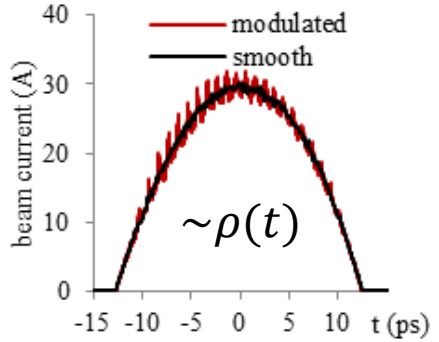






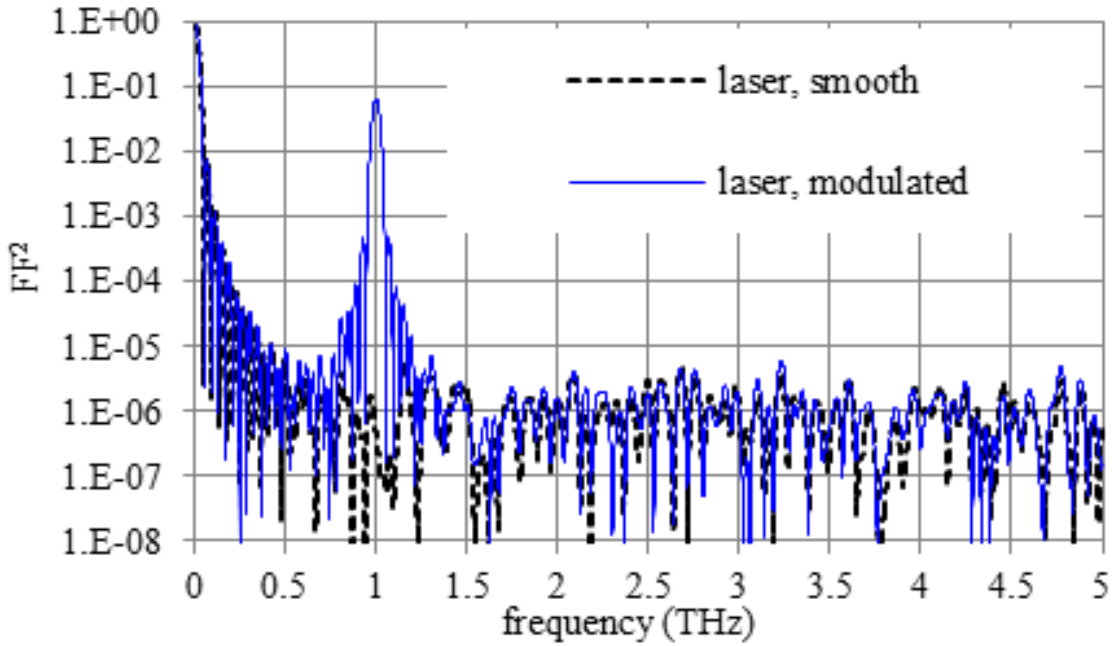
Electron bunch generation at PITZ

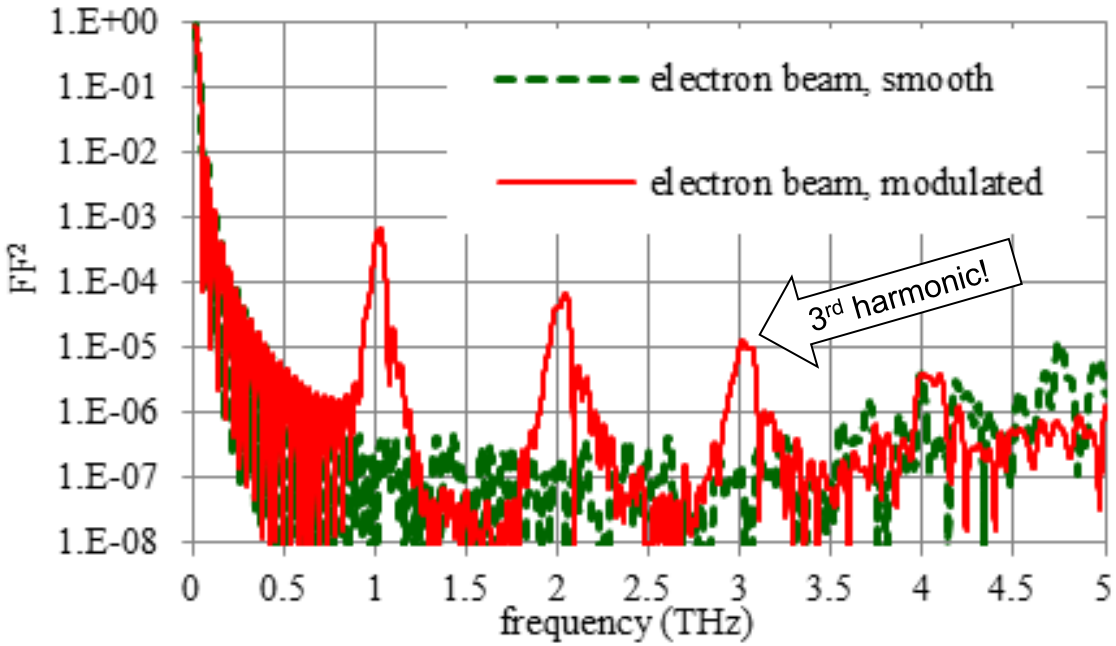
Analysis



form factor of the normalized longitudinal distribution of electrons $\boldsymbol{\rho(t)}$

$$FF(f) = \int_{-\infty}^{\infty} \rho(t)\, e^{-i2\pi f t} dt$$





Small frequency shift due to some RF compression

Conclusions and Outlook

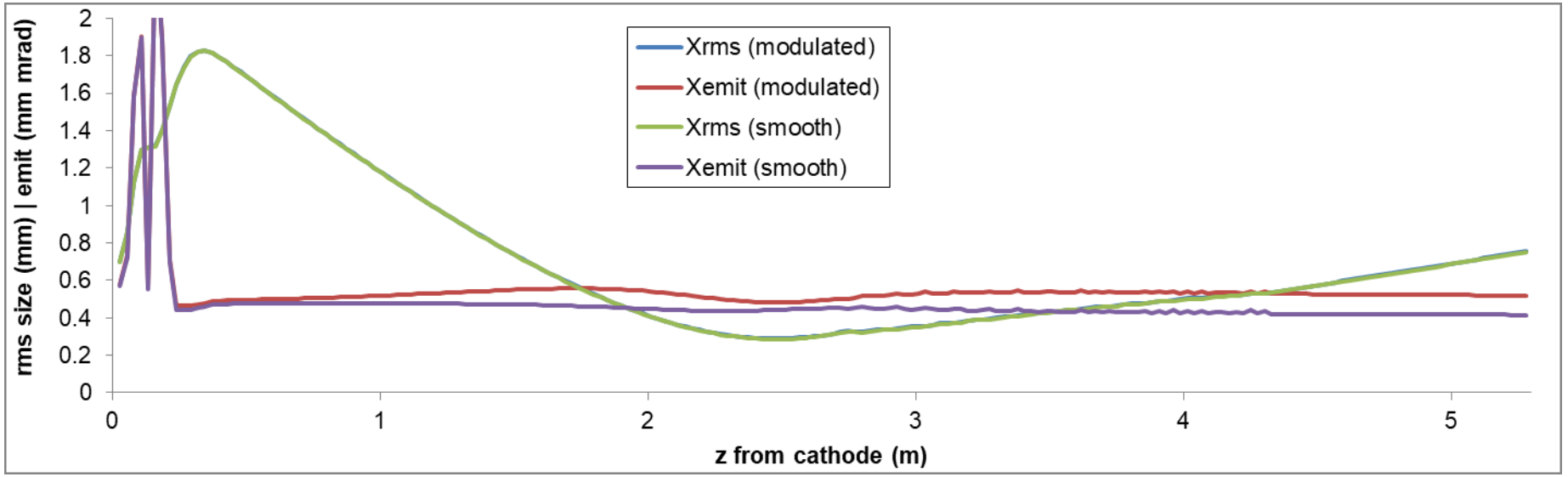
Preliminary

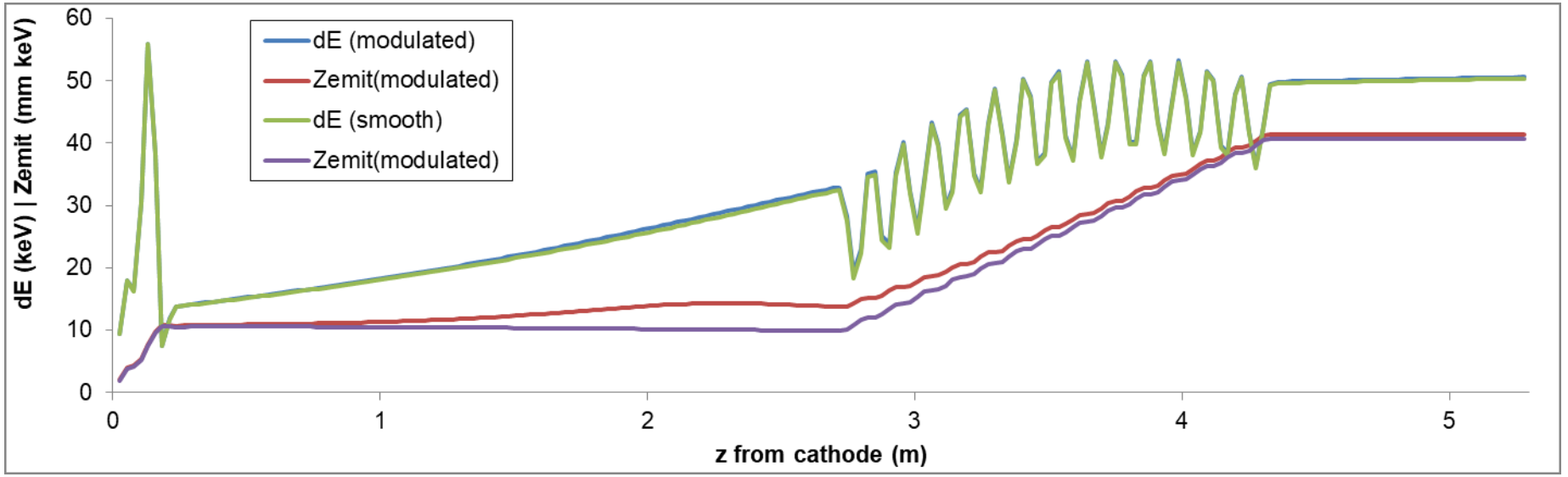
- Simulations with temporally modulated photocathode laser pulses applied to PITZ
- 50% modulation depth decreased by space charge / mirror charge effects, but still observable
- 3rd harmonics of 1ps modulations → 3Thz (100um) → still over noise level → might be interesting for THz seeding

- Possible next steps:
  - Optimize parameters (gun+booster phases, main solenoid, bunch charge, laser spot size at cathode) → backup slide
  - Study details → generation of higher harmonics (space charge – booster - plasma oscillations ?,…) → backup slide
  - +BC?
  - +3rd cavity for linearization?
  - Start-to-end simulations: track to the undulator + GENESIS (or other proper code)

Electron bunch generation at PITZ

Results of ASTRA simulations – beam parameters along beam line





Electron bunch generation at PITZ

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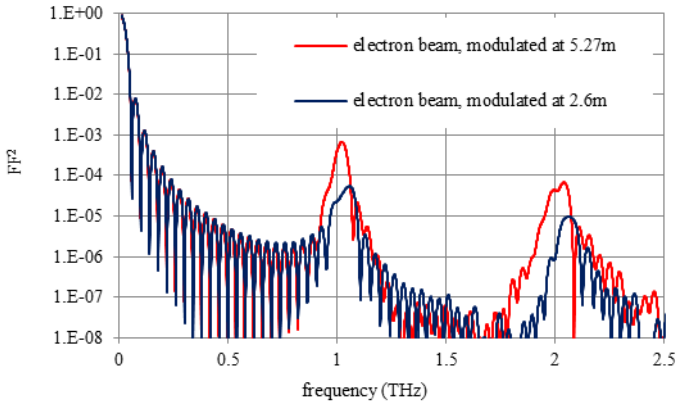

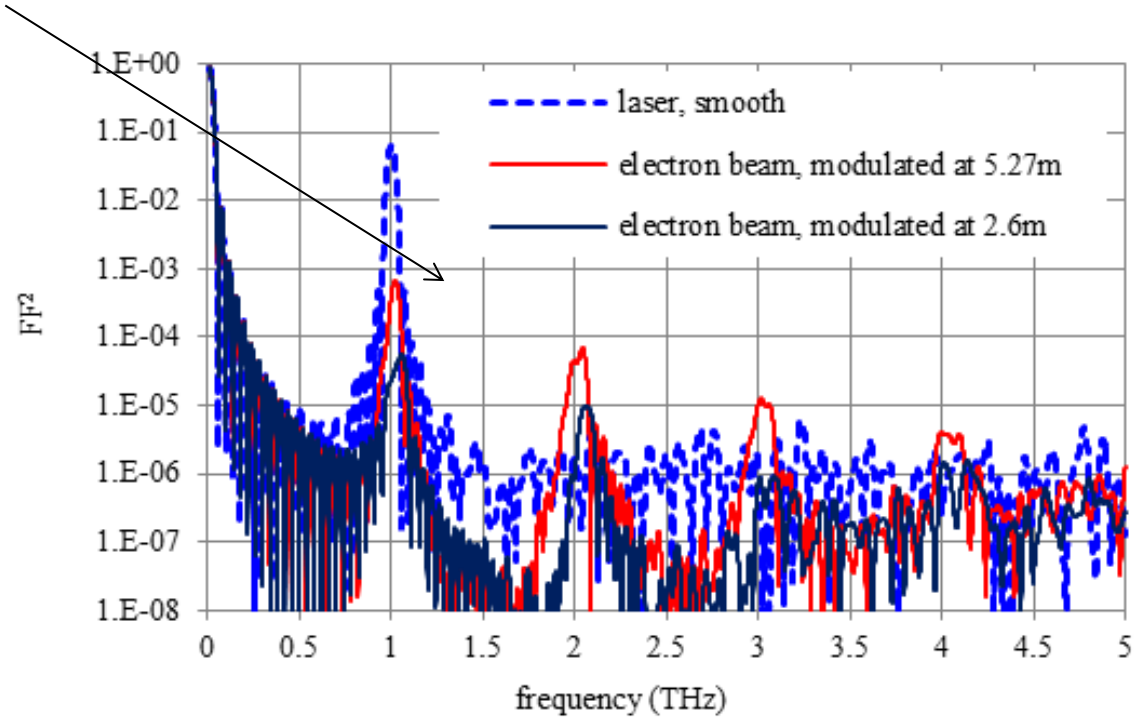

Electron bunch generation at PITZ

Gun+booster phase scan → gun phase=+10deg; booster phase=-10deg