FEL Simulations in the VUV Regime

Sven Reiche

DESY, Hamburg

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Future Light Sources

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Content

- The VUV FEL at the TESLA Test Facility
- Dependency on Electron Beam Parameters
- Undulator Field Errors
- Transverse Coherence
- Longitudinal Coherence
- Conclusion

Codes

FAST, FS2R, GENESIS 1.3, TDA3D

People

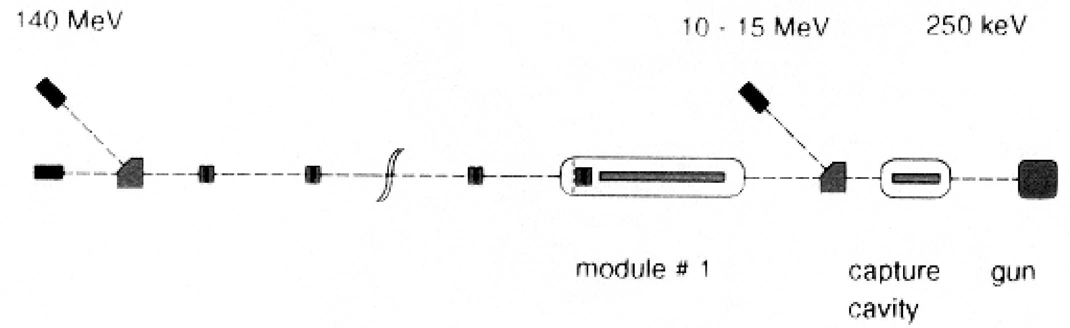
B. Faatz, S. Reiche, E.L. Saldin

E.A. Schneidmiller, M.V. Yurkov

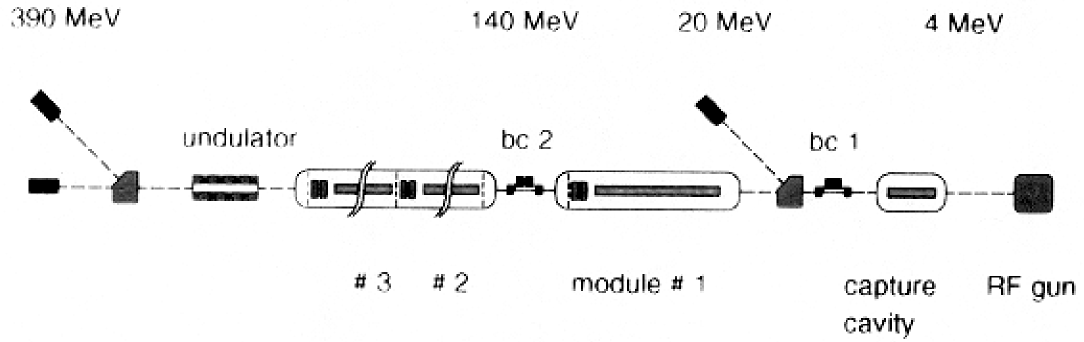
TTF-FEL Parameters

Parameters	Unit	Phase I	Phase II
Electron Beam			
Energy	MeV	230 - 390	1000
Peak Current	A	500	2500
Bunch Length (rms)	µm	250	50
Normalized Emittance (rms)	mm mrad	2	2
Energy Spread (rms)	MeV	0.5	1.0
Transverse Beam Size (rms)	µm	70	57
#Bunches / Train	–	7200	7200
Repetition Rate	Hz	10	10
Undulator			
Type		planar	planar
Length	m	15	30
Period Length	cm	2.73	2.73
Magnetic Peak Field	T	0.497	0.497
Undulator Parameter (rms)	-	0.894	0.894
Radiation			
Wavelength	nm	120 - 40	6.4
Bandwidth (rms)	%	0.7 - 0.4	0.5
FEL-Parameter	10^{-3}	4.6 - 2.8	2.1
Diffraction Parameter	-	1.1 - 2.3	14
Saturation Power	GW	0.23 - 0.5	2.4
Saturation Length	m	13.5 - 20.0	24.0

TTF Linac and TESLA FEL Linac

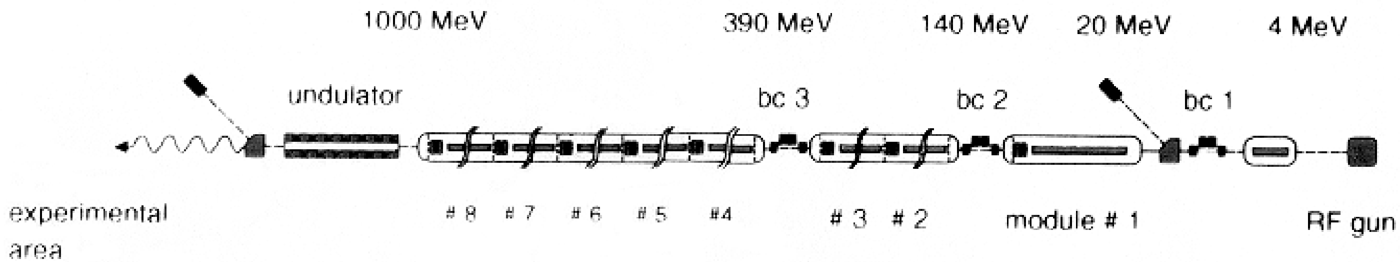


1997
commissioning of injector and module #1



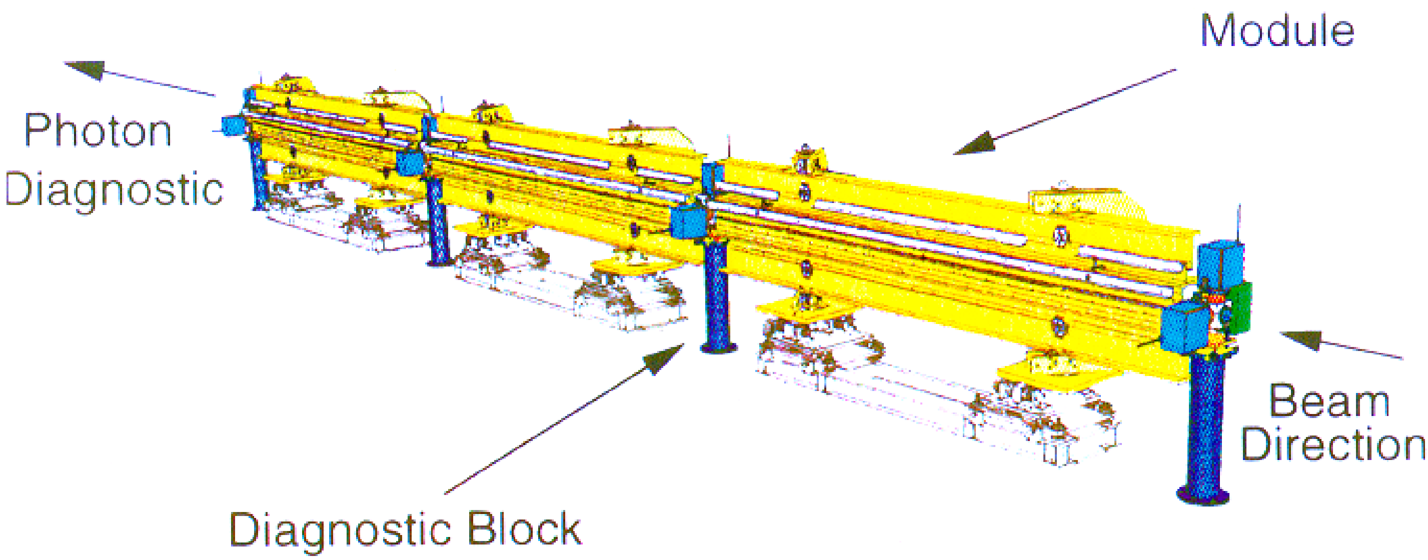
spring 1998
installation of RF gun
summer 1998
installation of modules #2 and #3
installation of bunchcompressor 2
beam tests with three modules

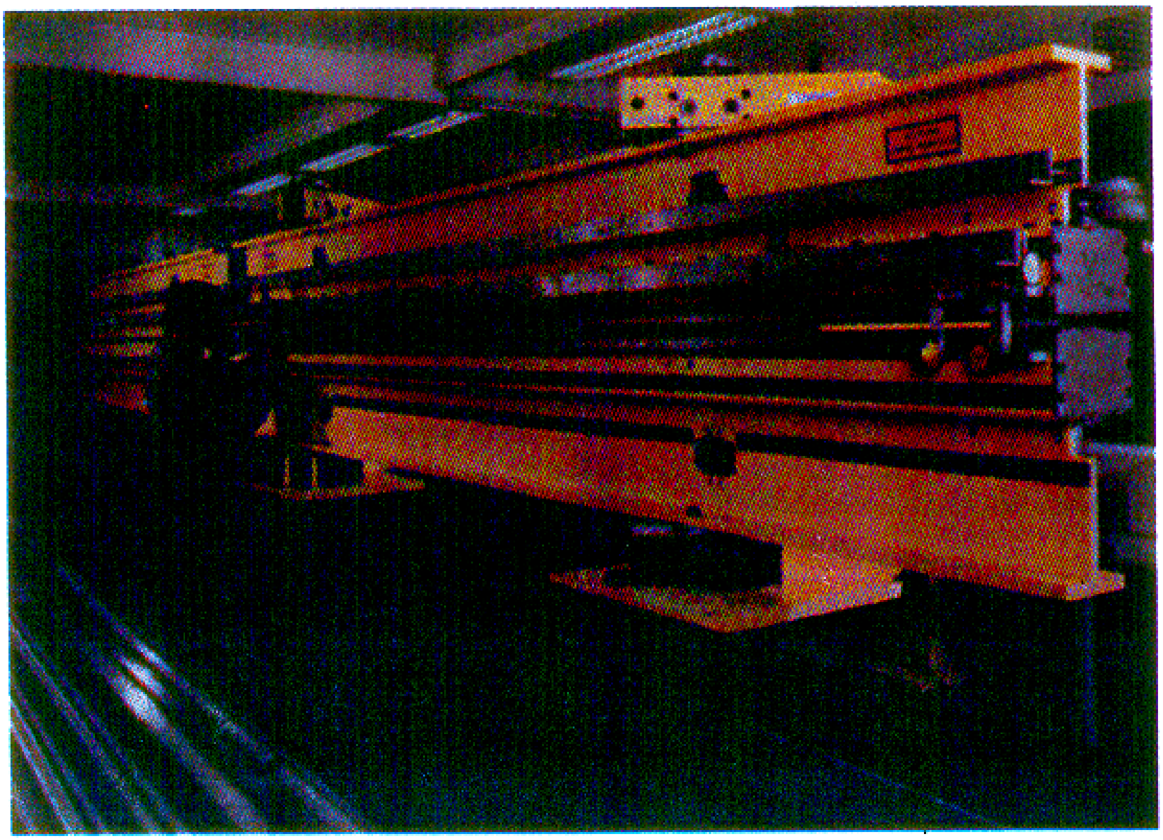
1999
installation of undulator
SASE FEL proof of principle



>2000
installation of more modules
long undulator for 1-2 GeV SASE FEL

The TTF-FEL Undulator



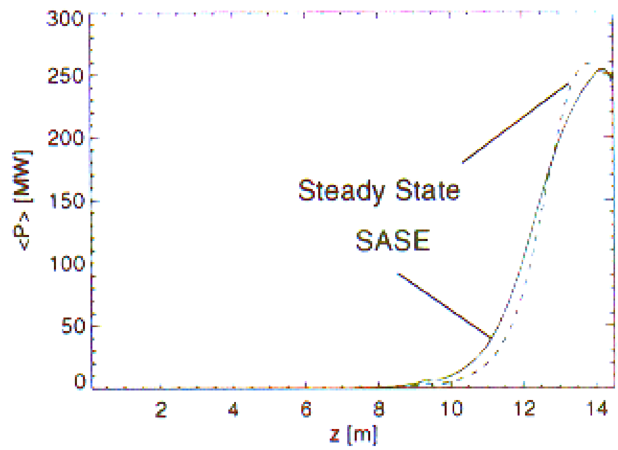


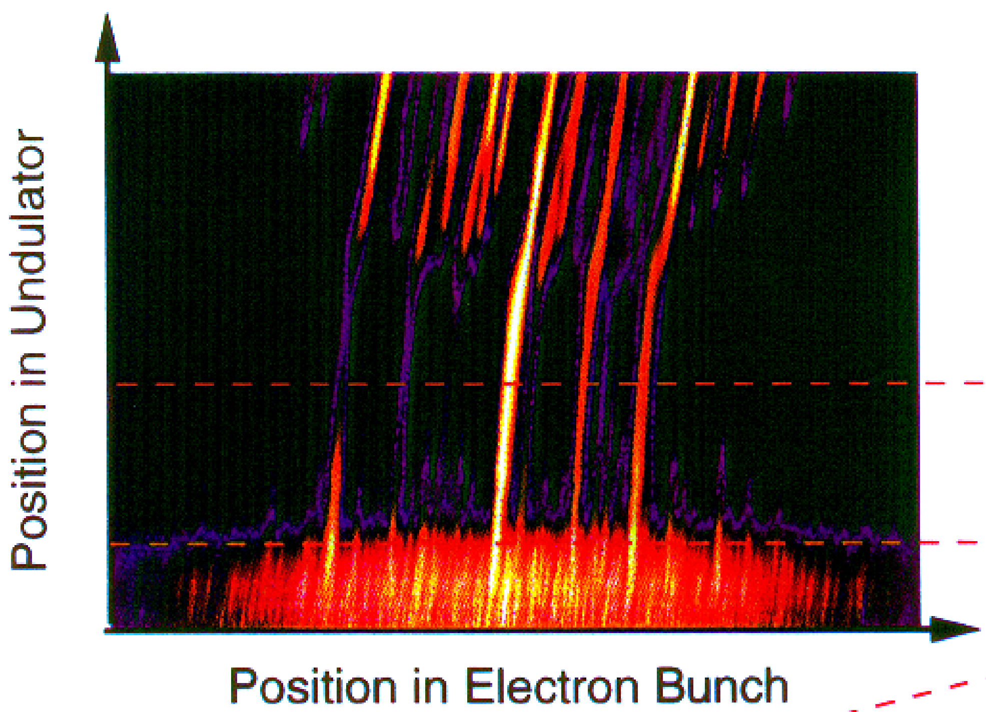
The SASE FEL Radiation Pulse

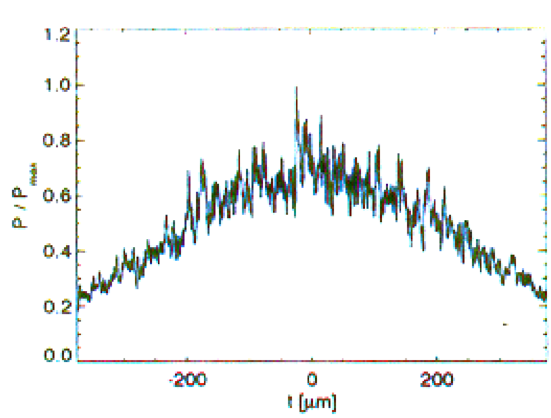
Growth of Spikes + Reduction of Minimum Radiation Power

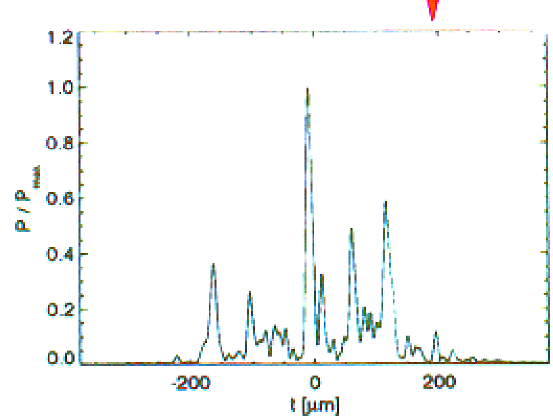
→ Growing Coherence

(Slippage & Diffraction)

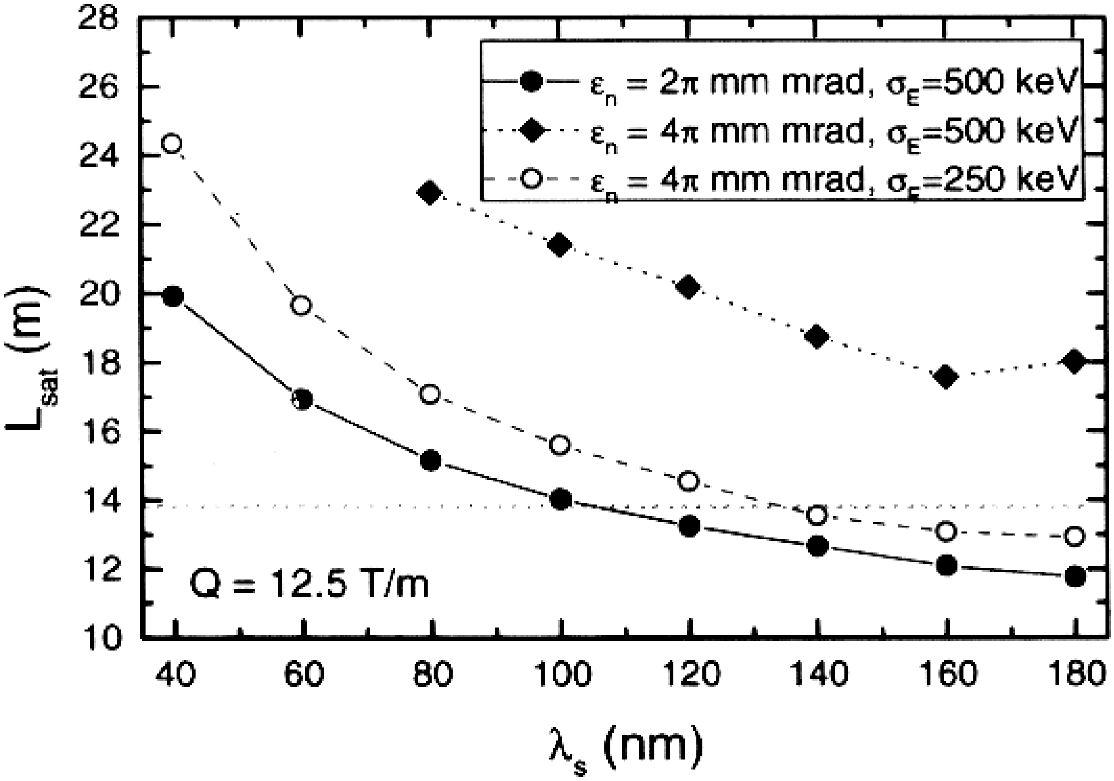


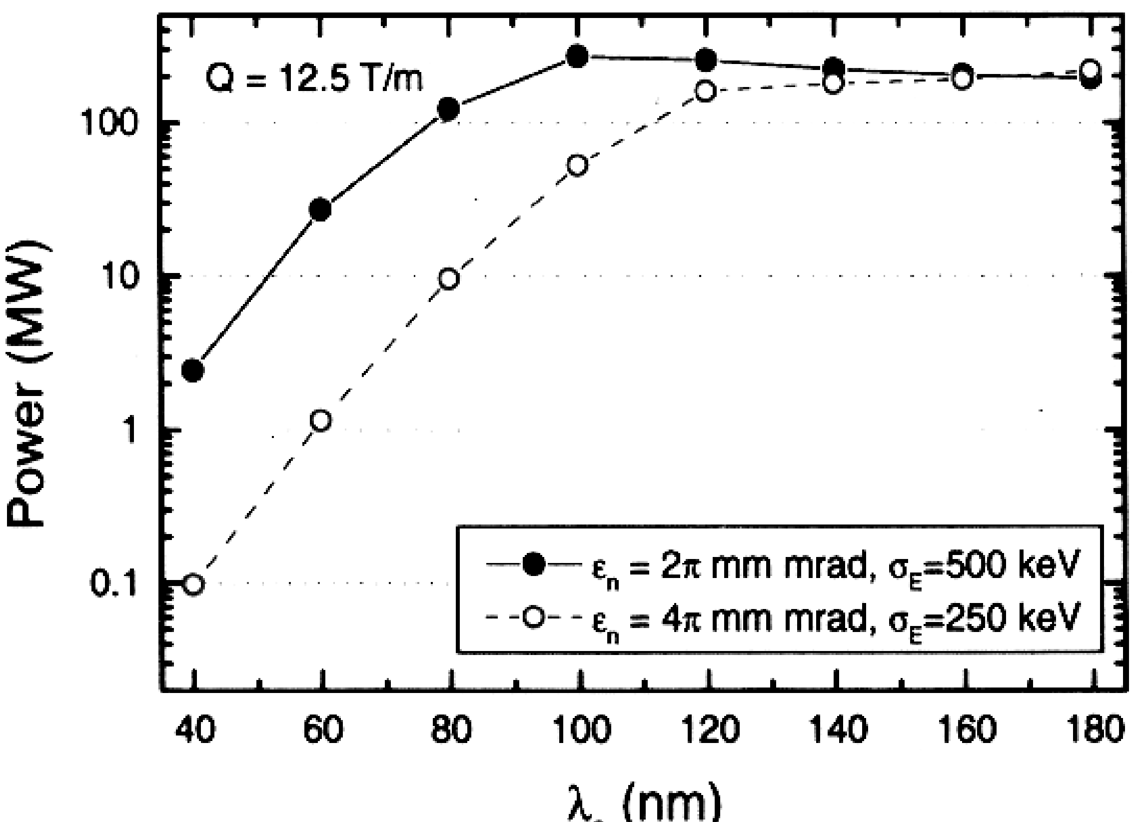




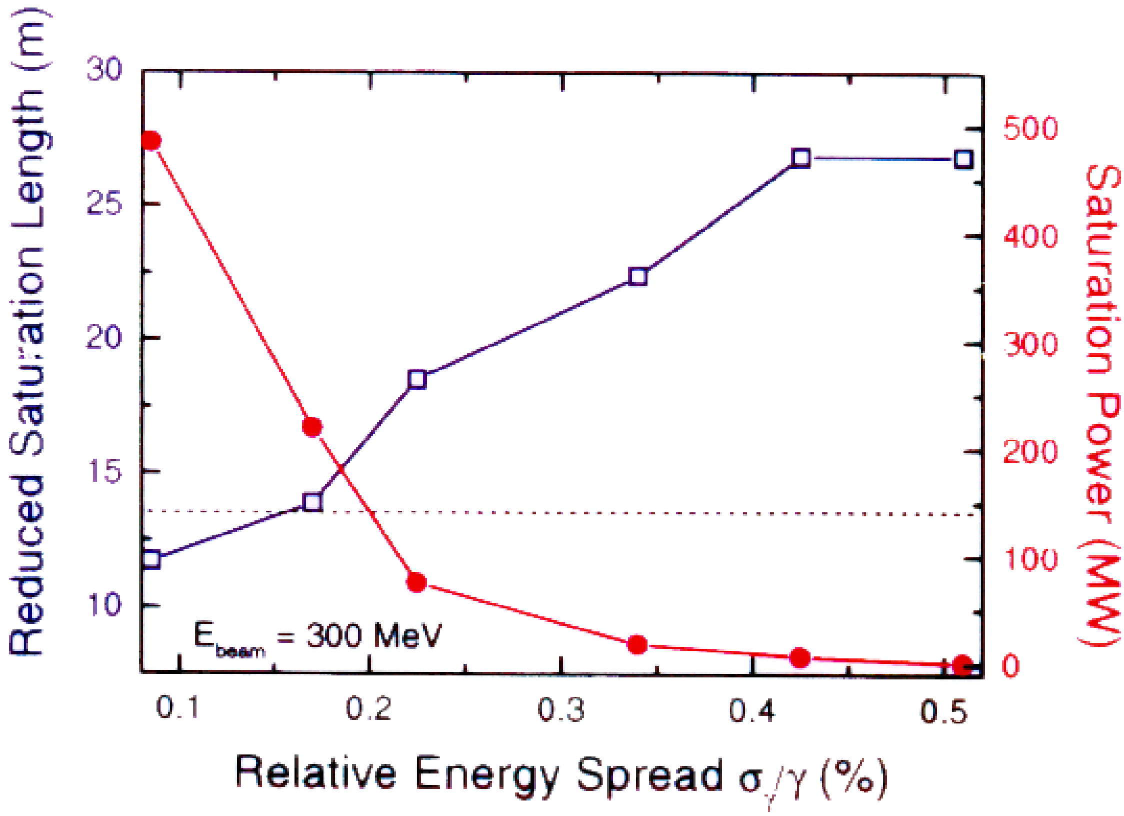


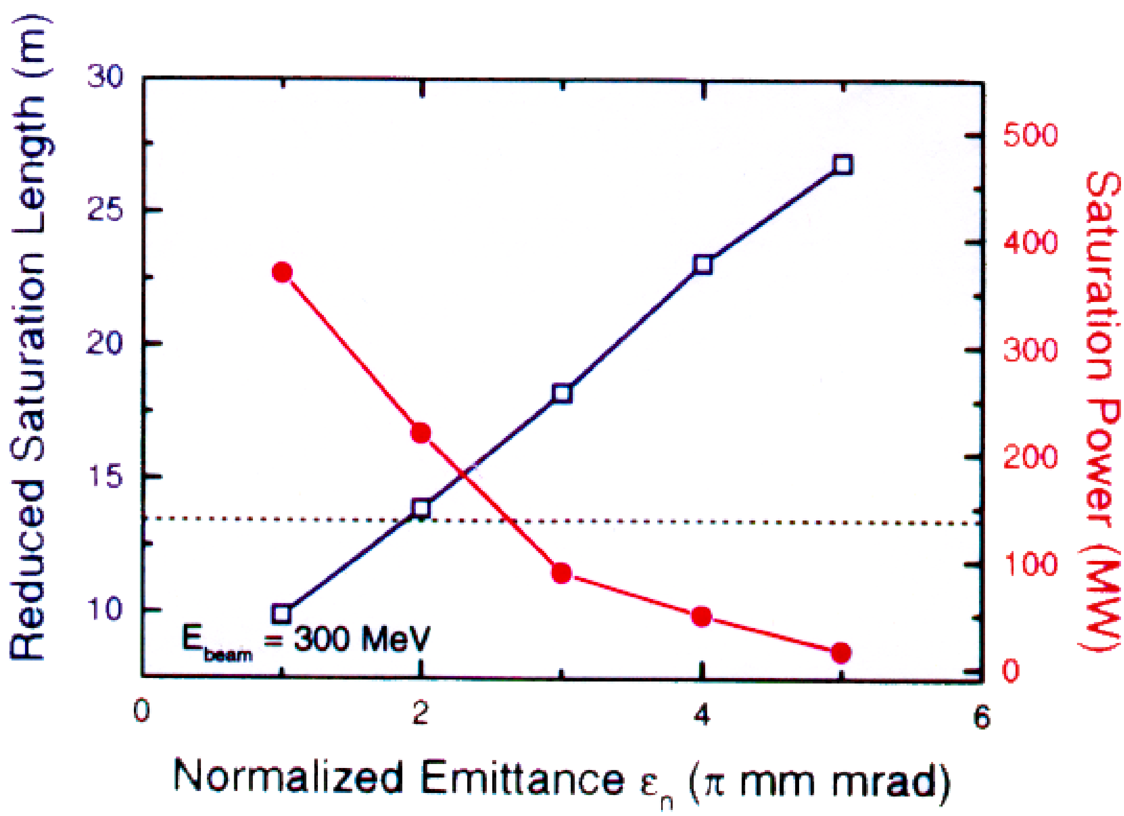
Performance of the TTF-FEL Phase I





Electron Beam Parameters





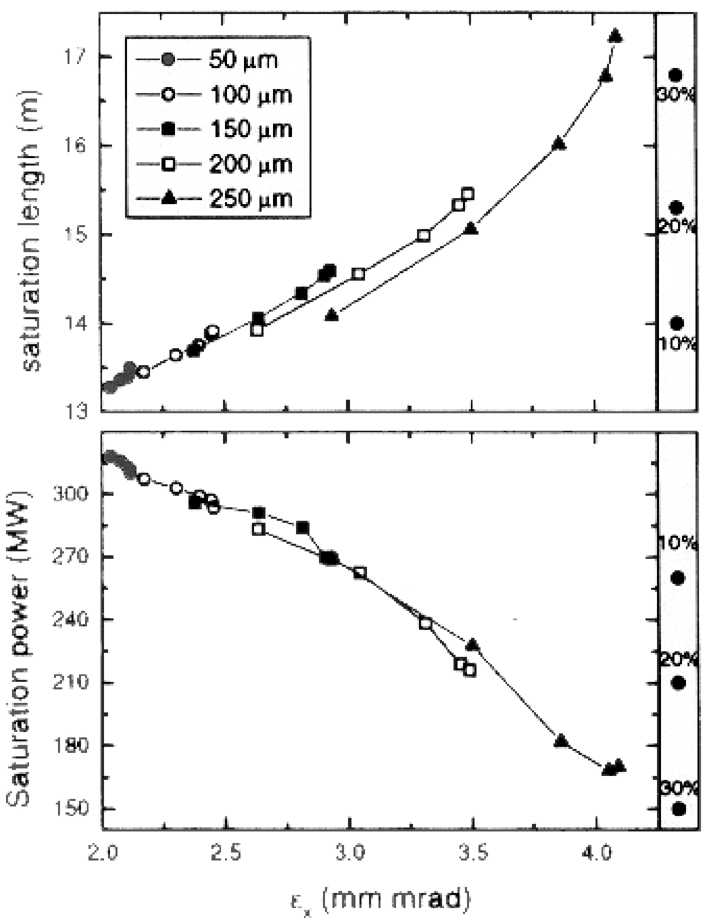
Electron Beam Halos

Model: Gaussian Distributions for Core and Halo

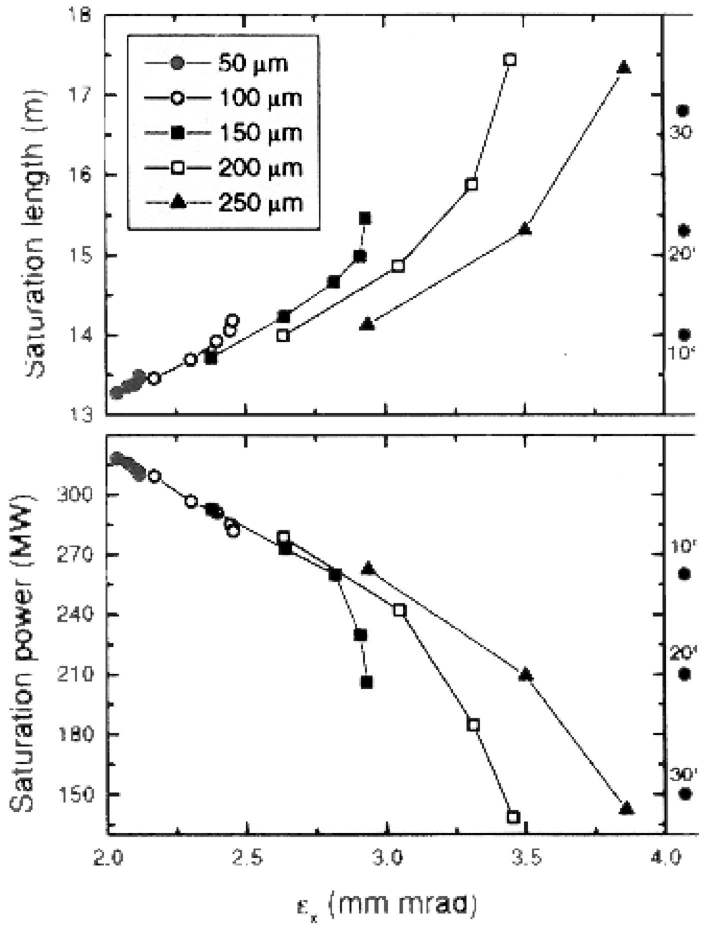
Separation: 50 - 250μm

Variation: 10 - 50 % of Electrons in Halo

Beam matched to FODO lattice



Core matched to FODO lattic



For matched beam, emittance is universal parameter to described FEL performance.

Collimation of halo is only usefull if separation is large to avoid oscillation of the core around the undulator axis.

Undulator Field Errors

→ Transverse Motion of Electron Beam Centroid

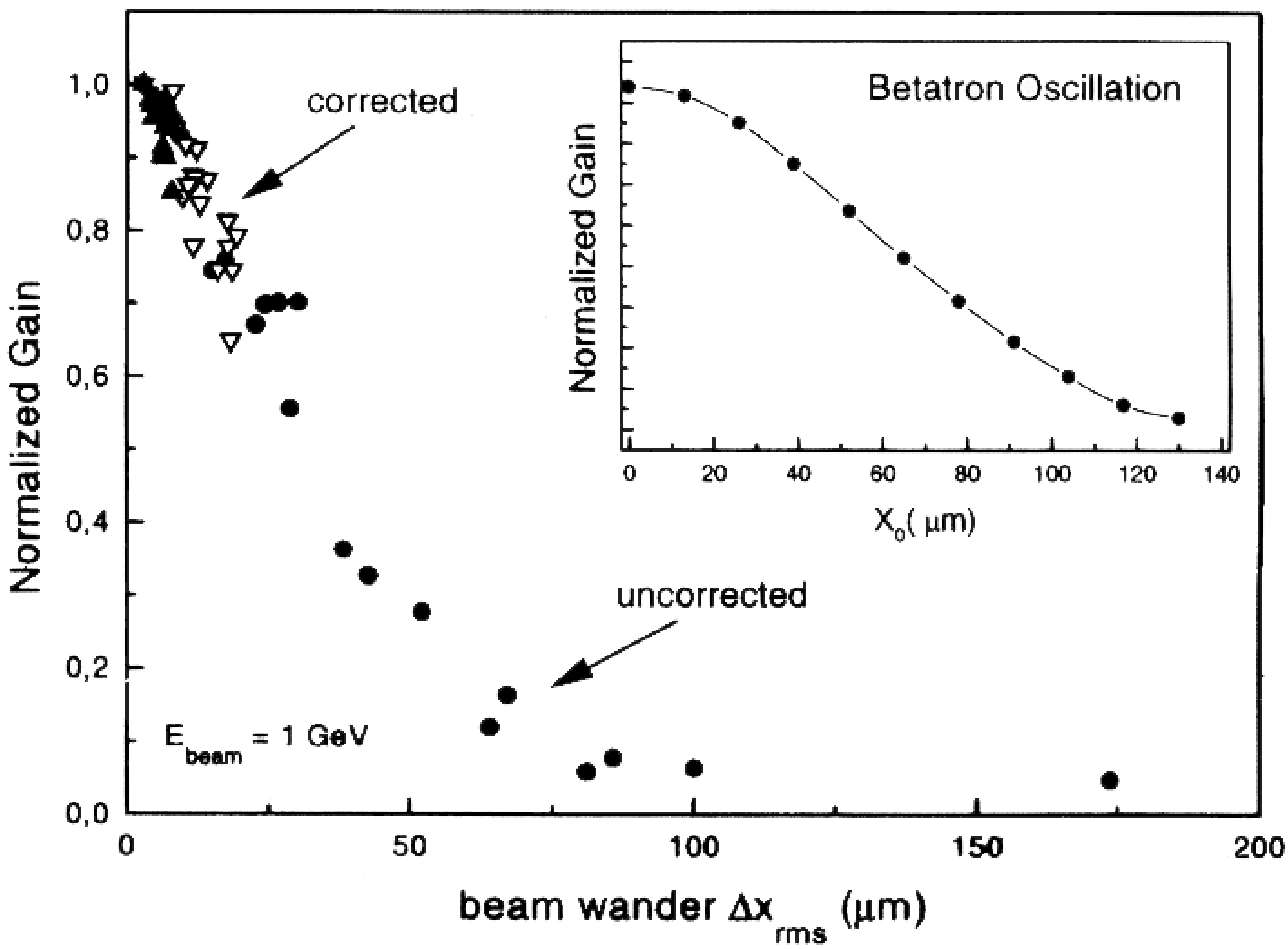
→ Less Transverse and Longitudinal Overlap

→ Reduced FEL Gain

Strong Correlation:

Average Beam Displacement ↔ FEL Gain

- Errors (Undulator Field, Quadrupole Misalignment)
- Efficency of Correction Schemes
- Off-Axis Injection ($X_0 = \sqrt{2}\,\Delta x_{rms}$)



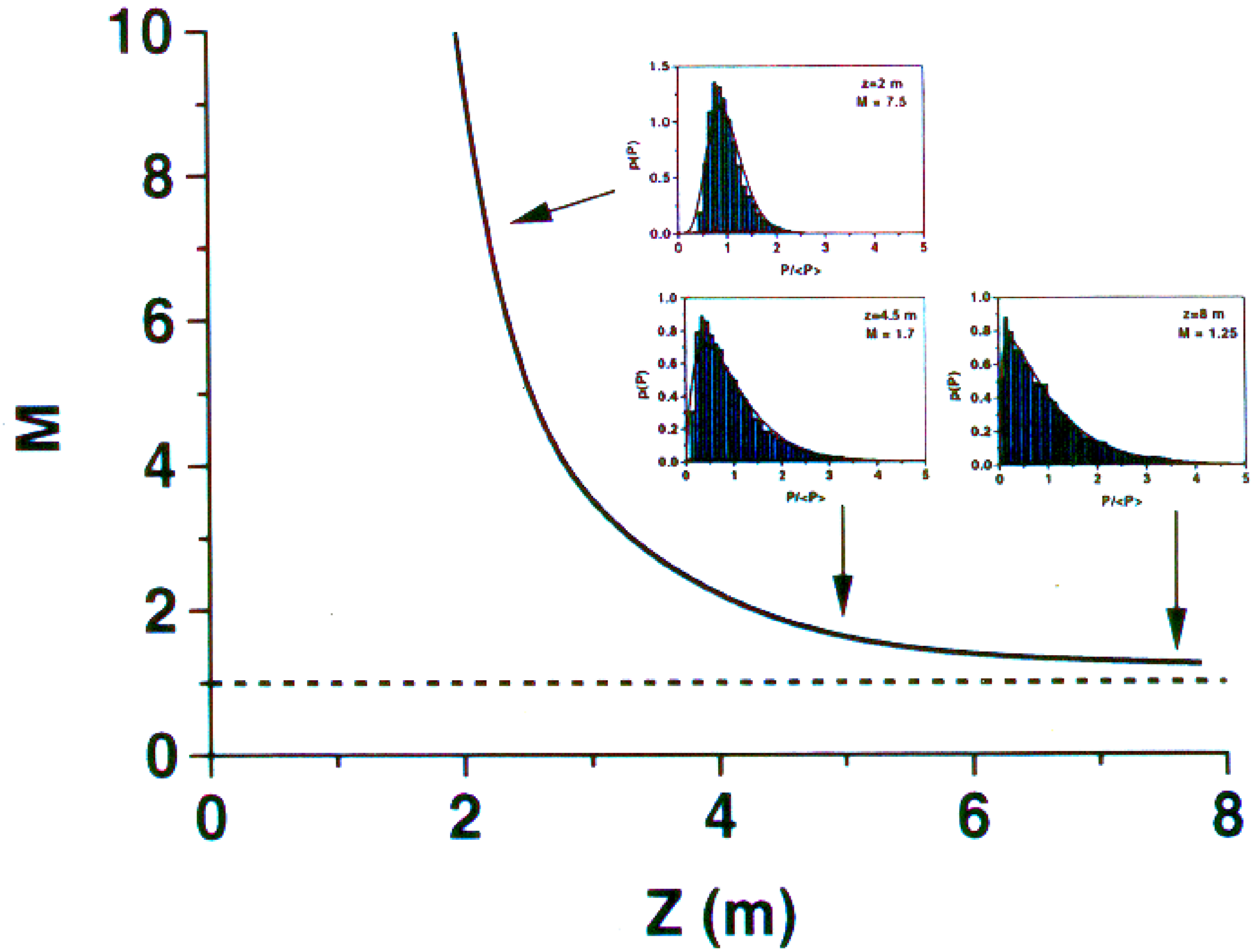
Formation of Transverse Coherence

Instantaneous Radiation Power =
Sum of Radiation Power over all Transverse Modes

Fluctuation follows Gamma distribution

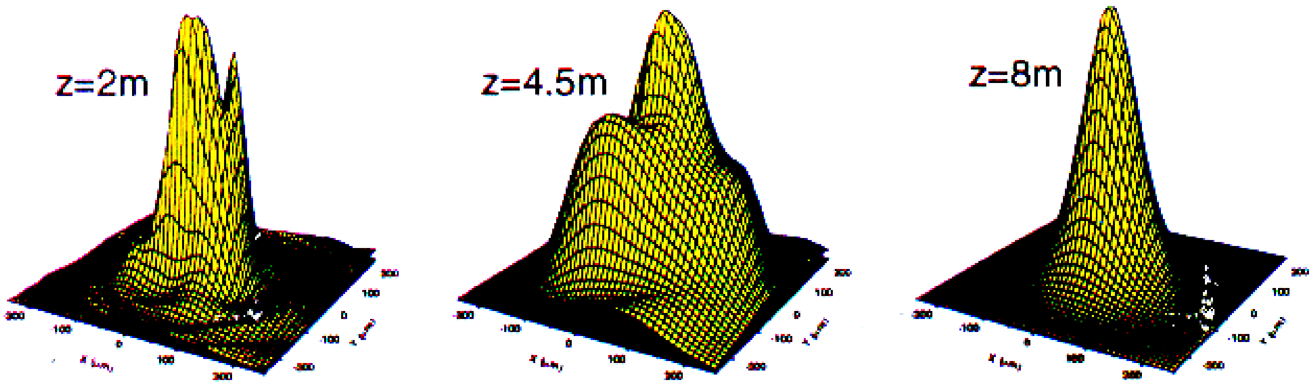
→ M-Parameter = Average Number of Transverse Modes

Transverse Coherence: Only one Mode is present (M =1).

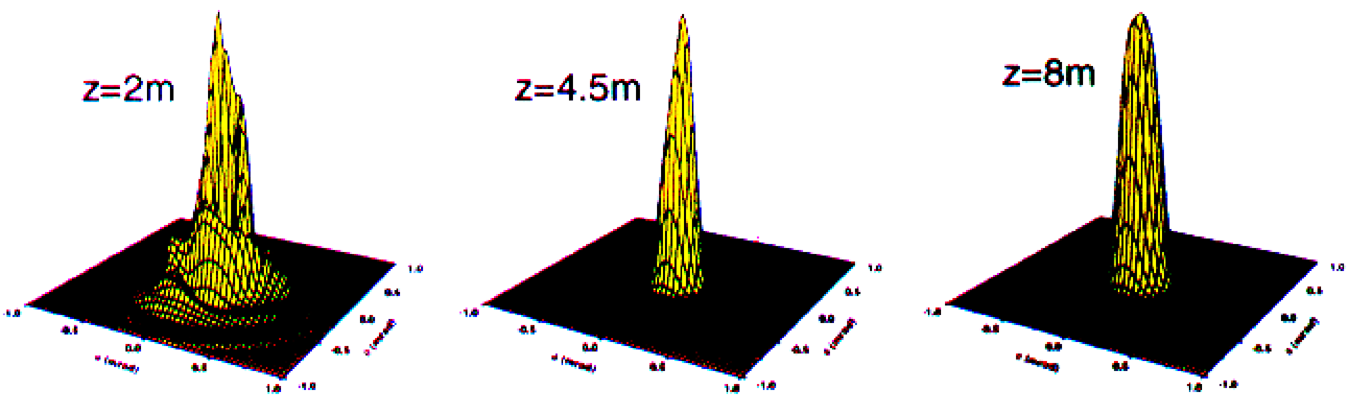


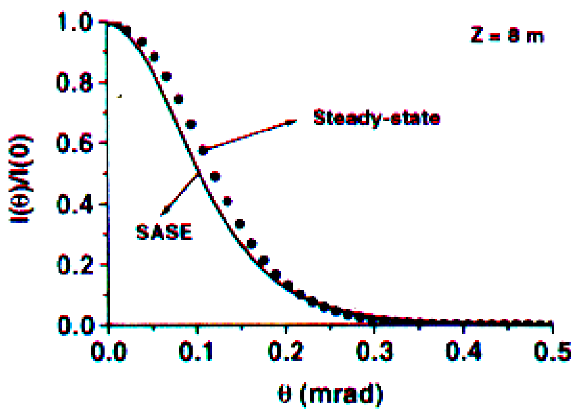
Radiation Field Distribution

Near Field



Far Field



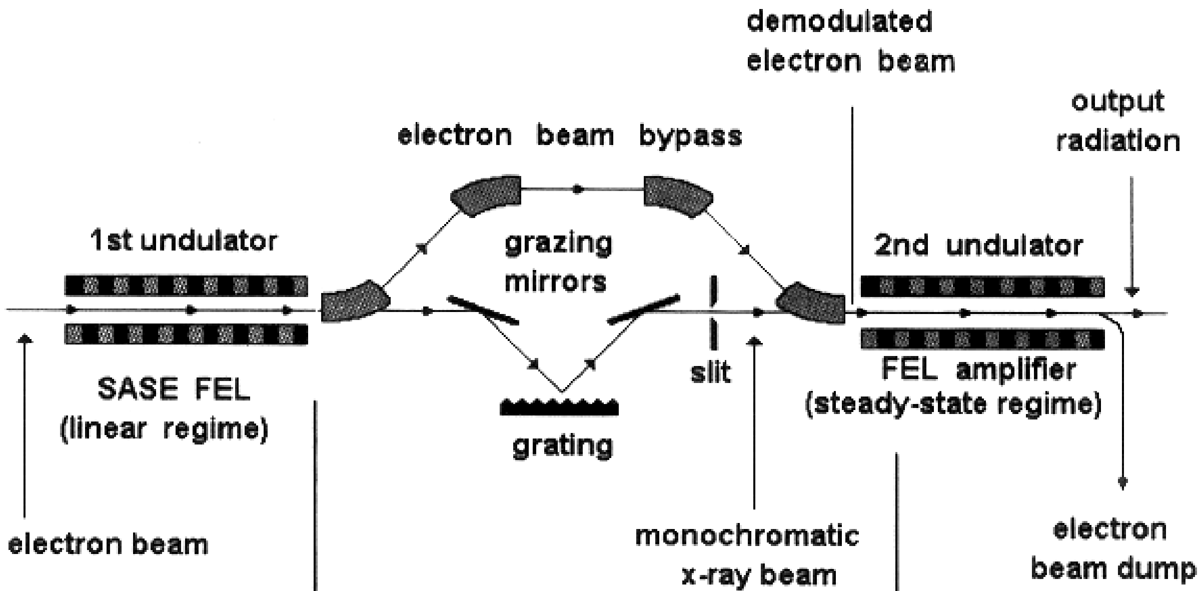


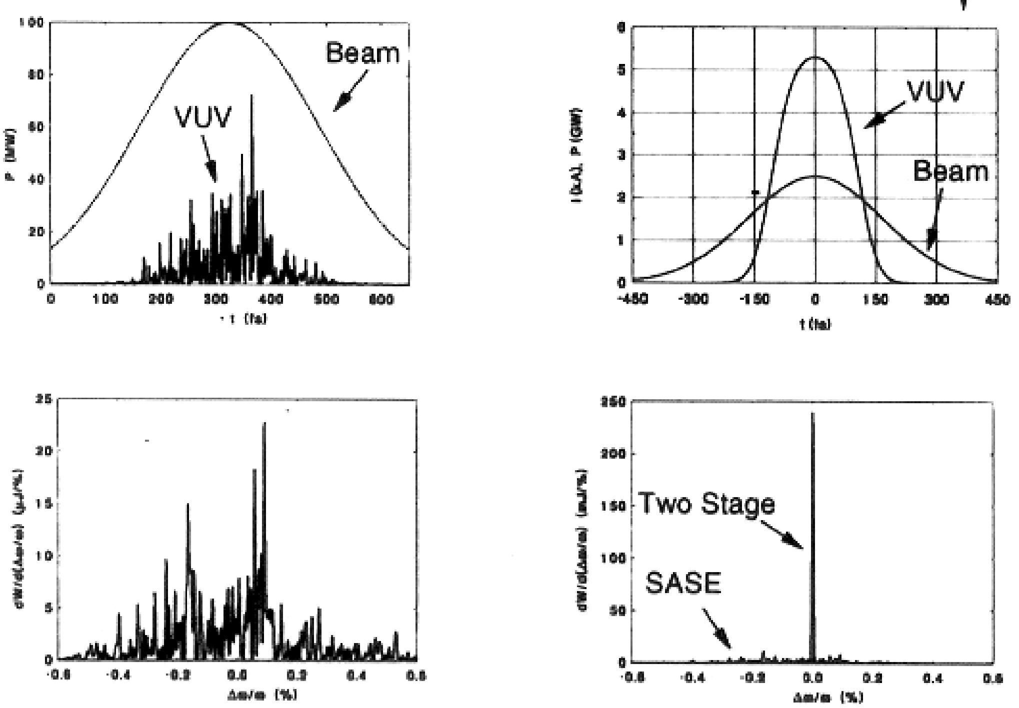
In the linear regime the average angular divergency is a measure of the degree of transverse coherence.

Longitudinal Coherence

SASE FEL at 1 GeV ⟶ Longitudinal Coherence: 2 fs

Two Stage FEL
- 1st Undulator as SASE FEL
- Longitudinal Coherence by Monochromator
- 2nd Undulator as FEL Amplifier





Deep Saturation

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Reduced Fluctuation

Conclusion

Code Optimization for Different Purposes

- General Design
  (Study of Parameter Space)

- Detailed Design
  (Field Errors, Wakefields)

Results

- Diffraction large enough to reach transverse coherence
- Longitudinal Coherence only by Two-Stage FEL or RAFEL
- Strong Focussing & Beam Alignment needed.
- Wakefields - under study