Effect of Wall Roughness on LCLS FEL Performance

Heinz-Dieter Nuhn, SLAC / SSRL

April 8, 1999

- FEL Gain Dependence on Correlated Effects
- Dynamic Energy Correlation
- Wall Roughness Simulation

Heinz-Dieter Nuhn, SLAC / SSRL
email: nuhn@slac.stanford.edu

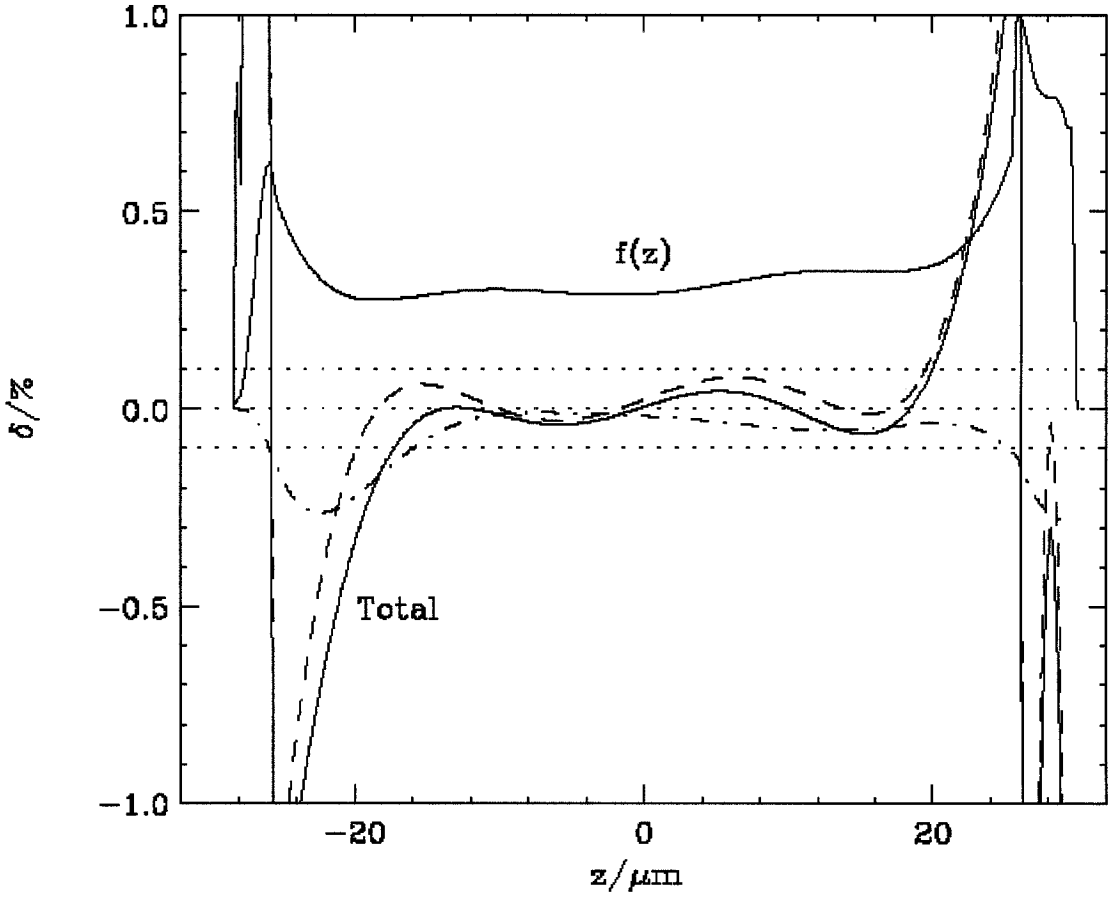
FEL Gain
Dependence on Correlated Effects

- Correlation generated in LINAC. (Static)
  - Slice Emittance Increase
    - Insignificant.
  - Slice Energy Spread Increase
    - Insignificant.
- Slice energy change inside undulator. (Dynamic)
  - Slice Emittance Increase
    - Emittance degradation insignificant.
  - Energy Change
    - Coherent energy loss from
      Spontaneous Synchrotron Radiation
      Resistive wall wakefields
      Requires tapering.
    - Loss of average slice energy during passage through undulator from
      Resistive wall wakefields
      Roughness wakefields
      Depends on position of Slide within bunch.
      Needs to stay within tolerances set by simulations.

Heinz-Dieter Nuhn, SLAC / SSRL
email: nuhn@slac.stanford.edu

Dynamic Energy Correlation

From the LCLS Design Study Report



1. Roughness (DASH), resistive wall (DOTDASH) and total (SOLID) wakefield generated within the 112-meter LCLS undulator for the non-gaussian bunch distribution, $f(z)$. A copper surface and a roughness of 100 nm is assumed. Just 55% of the electrons are altered in energy by less than ±0.1% (DOTTED). The bunch head is at left here.

Courtesy P. Emma, K. Bane

Heinz-Dieter Nuhn, SLAC / SSRL
email: nuhn@slac.stanford.edu

Wall Roughness Simulations

GINGER Model

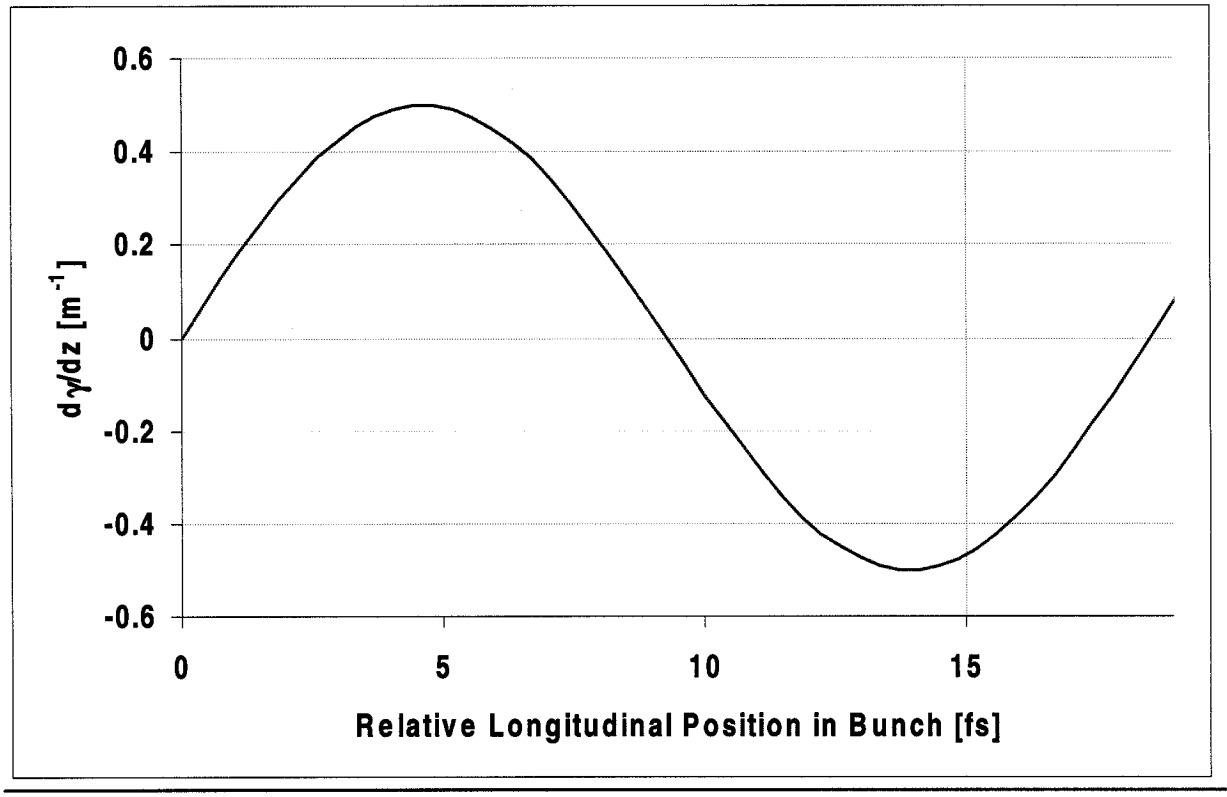
Added Term $d\gamma/dz$ (z_1) to FEL Equation in GINGER

z_1 is longitudinal position relative to electron bunch

Made $d\gamma/dz$ (z_1) Periodic

Allows to run GINGER with Periodic Boundary Conditions.

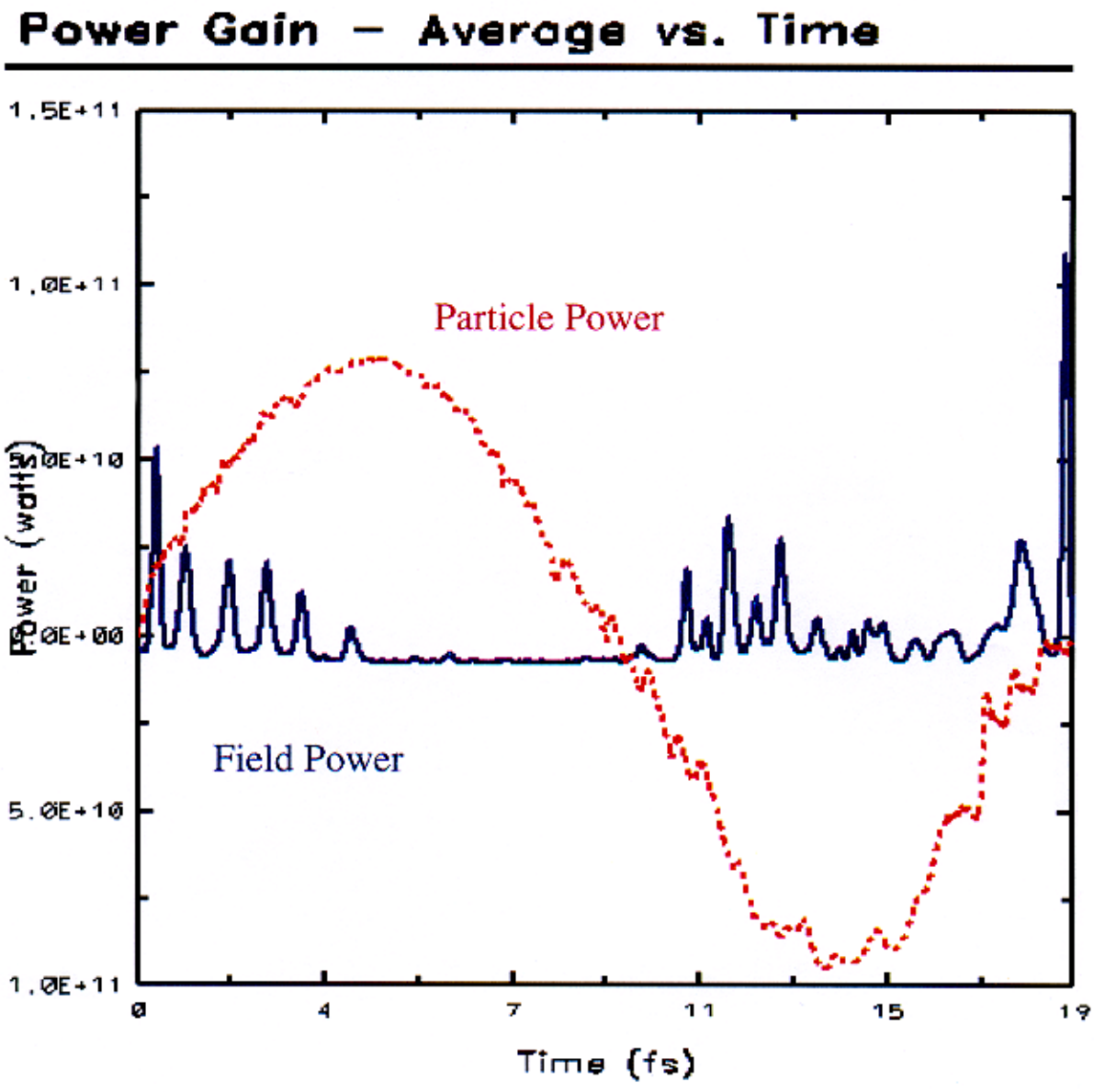
$d\gamma/dz = 0.5$ => $d\gamma = 50$ at end of Undulator. $\rho\gamma \sim 15$



Heinz-Dieter Nuhn, SLAC / SSRL
email: nuhn@slac.stanford.edu

Wall Roughness Simulations

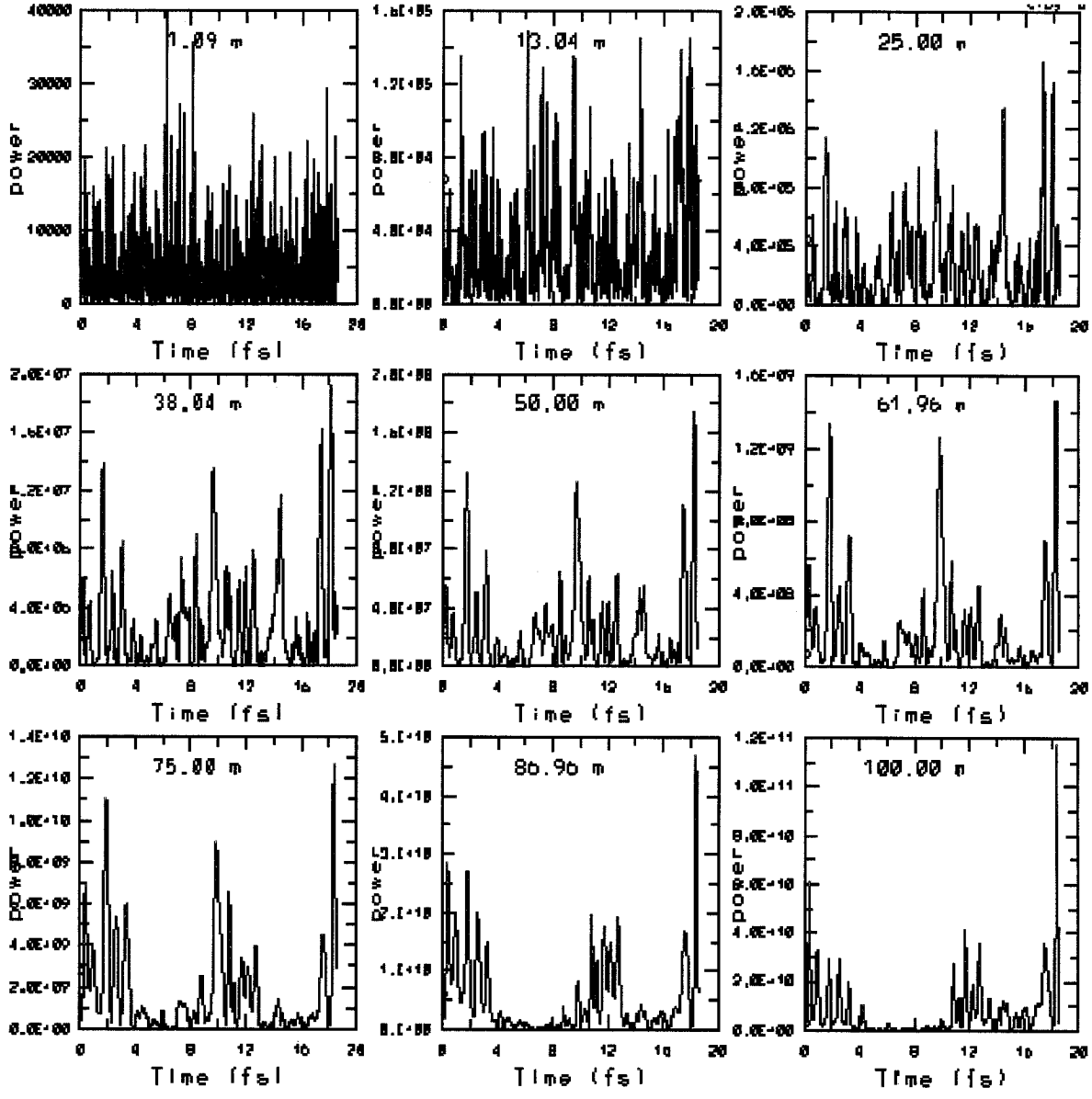
GINGER Results: Field and Particle Power



Heinz-Dieter Nuhn, SLAC / SSRL
email: nuhn@slac.stanford.edu

Wall Roughness Simulations

GINGER Results: Field Power

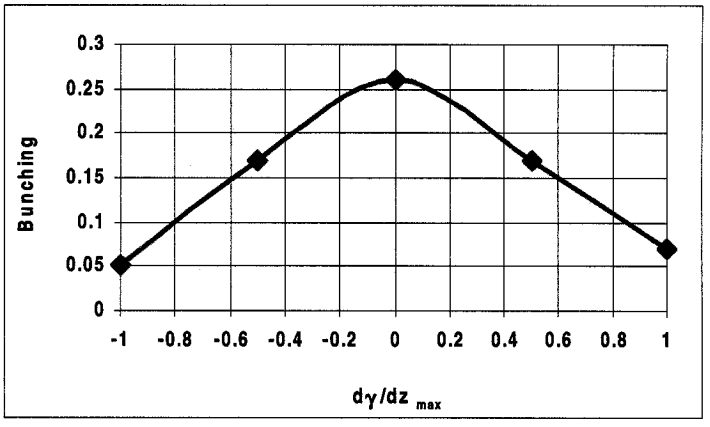


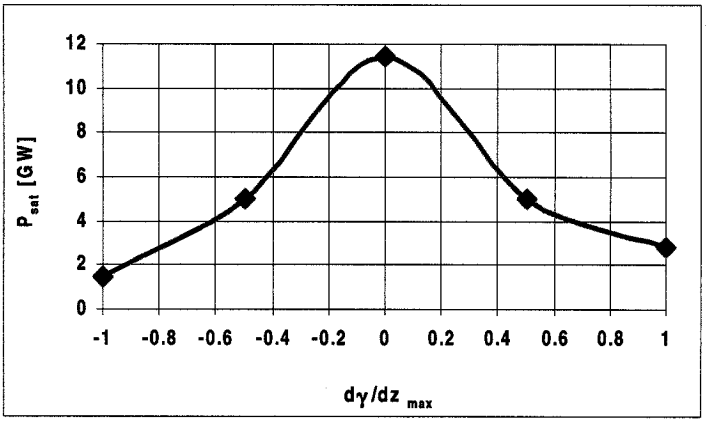
Heinz-Dieter Nuhn, SLAC / SSRL
email: nuhn@slac.stanford.edu

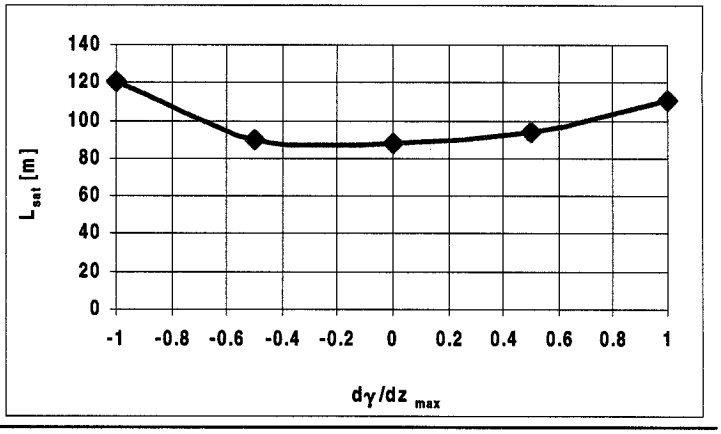
Wall Roughness Simulations

GINGER Results: Summary

$d\gamma/dz$	b_{max}	P_{max}	L_{sat}
-1	0.05	1.4	120
-0.5	0.17	4	90
0	0.26	11	88
0.5	0.17	5	94
1	0.07	2.8	110







Heinz-Dieter Nuhn, SLAC / SSRL
email: nuhn@slac.stanford.edu

Conclusion

- **Wall roughness wakefields in the undulator can accelerator or decelerate bunch slices.**
- **Amount of acceleration or deceleration depends on slice's position within the bunch.**
- **Average effect can be compensated by micro-tapering.**
- **Remaining effect needs to be kept to below 0.1 % over the length of the undulator.**

Heinz-Dieter Nuhn, SLAC / SSRL
email: nuhn@slac.stanford.edu