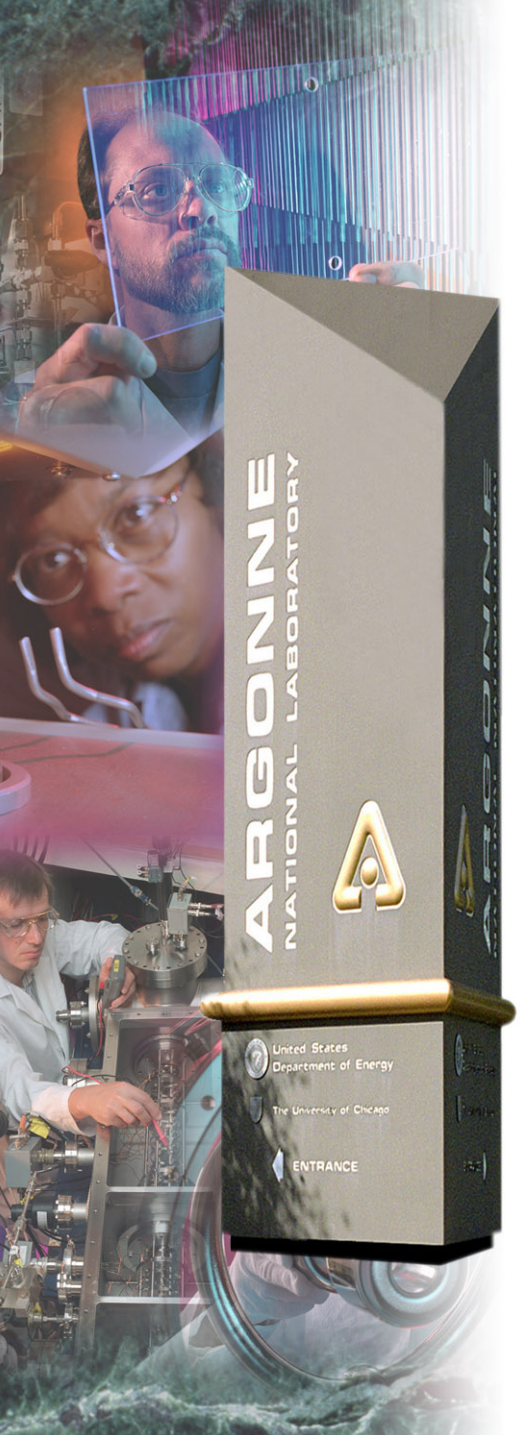


High Performance Computing in Accelerator Physics

Yong-Chul Chae,
Accelerator System Division

CARA Parallel Computing Meeting, June 8,2005

Argonne National Laboratory

Office of Science
U.S. Department of Energy

A U.S. Department of Energy
Office of Science Laboratory
Operated by The University of Chicago

Short Bunch Simulation

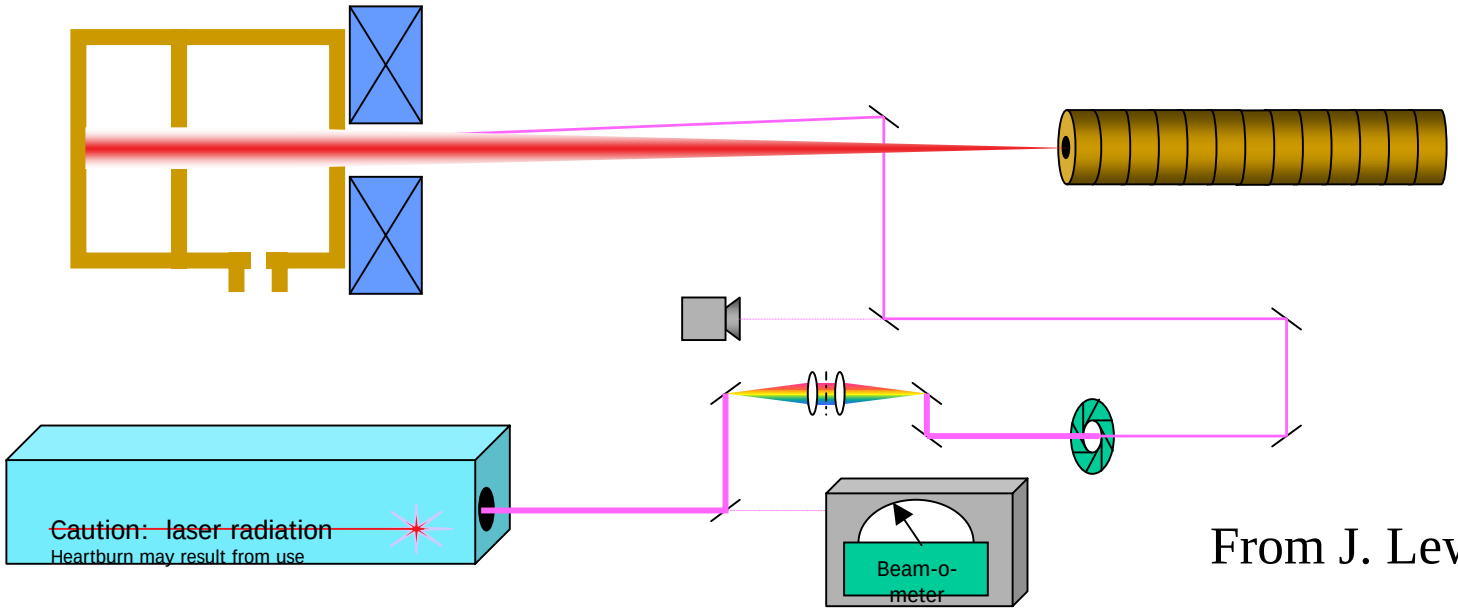
- **Bunch length of interests down to 1 ps**
  - Advanced Photon Source (APS)
  - Linear Coherent Light Source (LCLS)
  - International Linear Collider (ILC)
  - Coherent THz source
- **Interactions with accelerator structures generate wakefield**
  - Shorter the bunch, stronger the field; 3D time-dependent electromagnetic field
  - Collective effect in the APS storage ring
  - High brightness beam production for LCLS
  - High luminosity in ILC
  - Coherence in THz source
- **Common theme: short bunch interaction with accelerator structures and radiator materials.**
- **Short bunch simulation demands High Performance Computing**

APS: Impedance Database II

- **The Impedance Database**
  - Wake potentials of 5-mm-long bunched beam
  - 3D Electromagnetic Field Solver MAFIA (serial program)
  - Impedance as function of frequency up to 20-30 GHz
  - Used to predict the collective effects in the APS storage ring
  - Found that we need the impedance range over 100 GHz

- **Impedance Database II**
  - Wake potentials of 2-mm-long or less bunched beam
  - Typical domain size 10 cm x 10 cm x 100 cm
  - Required number of cells is about 10 billion
  - Required memory is about 400 GB
  - Required speed is about 200 GFlop to finish in 24 hours

High Brightness rf-Gun



From J. Lewellen

- HB Beam: Q=1 nC, ε=1 μm, σ=(5 mm, 5 mm, 10 mm)
- Physics Involved: Wakefield, Space Charge, Cathode Surface, etc.
- Domain size: 20 cm x 20 cm x 100 cm
- Number of Cell and Memory: 10 billion cells, 400 GB
- Software: 3D wakefield + Particle in cell (PIC) + parallelized

International Linear Collider (ILC)

International Linear Collider
at Stanford Linear Accelerator Center

Wakefield Calculations

- Extensive 3-D modeling of the TESLA and the new Low-Loss SC cavity wakefields
  - Big computation: 768 processors and requires 300 GB memory
  - Mode rotation may be an important source of jitter
    - Need to understand if this is mostly systematic due to the coupler orientation or due to fabrication errors
    - Huge effect if it is systematic

- New Low Loss cavities have lower cryoloads but higher wakes
  - Big impact on design → may make 35 or 40 MV/m possible
  - Need to understand the wakefield implications

Interaction between a beam and a photonic crystal

- **Japan Universities-Laboratories Collaboration**
  - K. Yamamoto, et al, “Observation of millimeter-wave radiation generated by the interaction between an electron beam and a photonic crystal,” Phys. Rev. E 69, 045601 (2004).
- **MIT Plasma Fusion Science and Technology**
  - A. S. Kesar, et al, “Time- and frequency-domain models for Smith-Purcell radiation from a two-dimensional charge moving above a finite length grating,” Phys. Rev. E 74, 016501 (2005)
  - S. K. Korbly, et al,“Observation of Frequency-Locked Coherent Terahertz Smith-Purcell Radiation,” Phys. Rev. Lett 94, 054803 (2005)
  - Proposal modeling and design of photonic crystal based active radiation source
- **Advanced Photon Source**
  - Proposal modeling and design of photonic crystal based active radiation source ➔ Simulate 2D and 3D Photonic Band Gap Structure by using HPC

Proposal

- **Hardware**
  - Midrange-I: 200 GB, 200 GFlop
  - Midrange-II: 500 GB, 400 GFlop
  - High-End: 1TB, 1 TFlop
- **Software**
  - GdfidL: 3D EM, Particle-In-Cell, Parallel ➔ needs to own
  - MAFIA: 3D EM, Particle-In-Cell, Serial ➔ needs parallelized
  - Elegant: particle tracking, Serial ➔ needs parallelized
- **Priorities**
  - Impedance Database II
  - High Brightness Gun
  - ILC Wakefield
  - PBG/LH Material Based Radiator