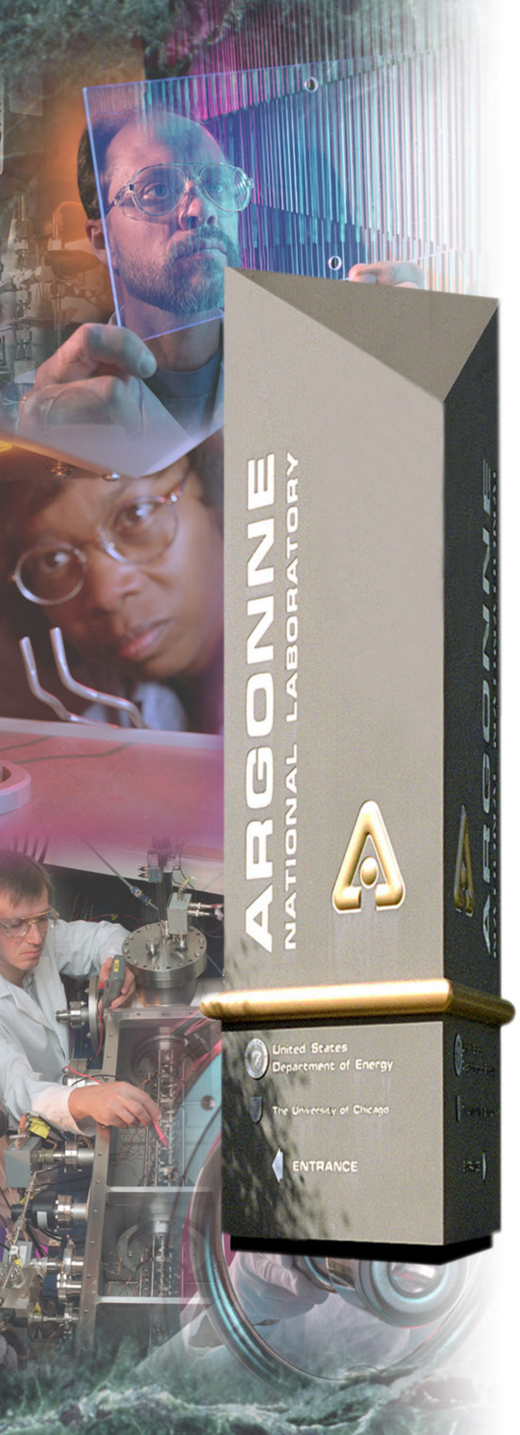

APS Short Pulse Project

Katherine Harkay

APS/CNM 2005 Users Meeting

Workshop 9: Generation and Use of Short X-ray Pulses at APS

May 6, 2005

Office of Science
U.S. Department of Energy

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

Feasibility study group

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Science drivers for ps x-rays

APS Strategic Planning Workshop (Aug 2004):

Time Domain Science Using X-Ray Techniques

"…by far, the most exciting element of the workshop was exploring the possibility of shorter timescales at the APS, i.e., the generation of 1 ps x-ray pulses whilst retaining high-flux. This important time domain from 1 ps to 100 ps will provide a unique bridge for hard x-ray science between capabilities at current storage rings and future x-ray FELs."

Atomic and molecular dynamics, coherent/collective processes:

- **Atomic and molecular physics**
- **Condensed matter physics**
- **Biophysics/macromolecular crystallography**
- **Chemistry**

Storage ring sources vs. FELs

2008: APS ~ps, 10^{13} ph/s (avg flux) (FY06 start assumed)

2008: LCLS <300 fs, 30 J/cm^2 (non-focused fluence)

2011: TESLA ~100 fs, 10^{19} W/cm^2 (focused intensity)

Storage ring "crabbed" sources delivering hard x-ray pulses down to ps range are complementary to future x-ray FELs

Storage rings can provide

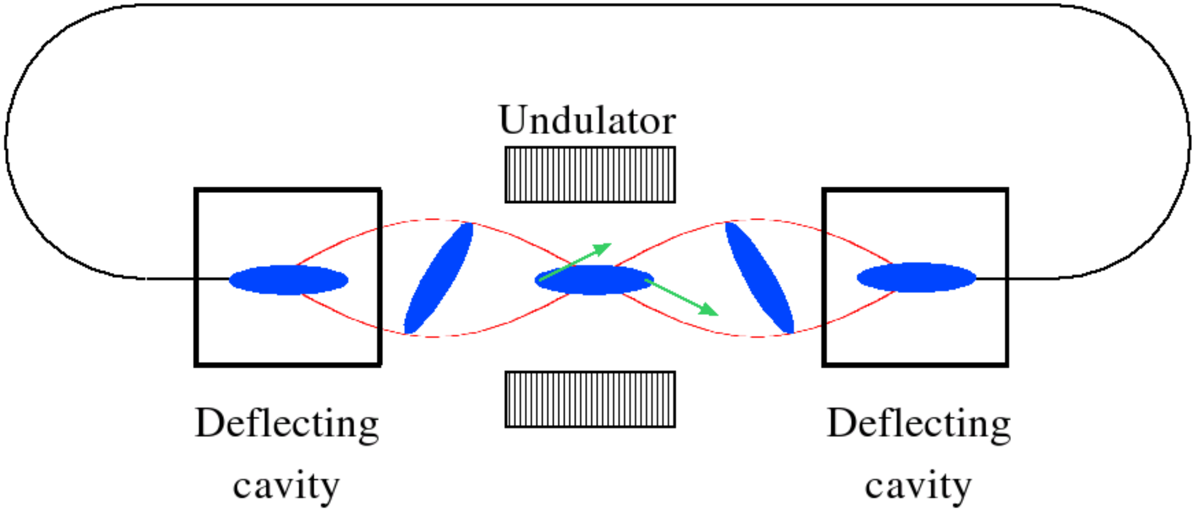
- ~1 ps pulses
- Energy tunability
- Spectral stability
- Flux comparable to 100 ps
- High repetition rate

X-ray FELs can provide

- fs pulses
- Ultrahigh peak power
- Ultrahigh brightness
- Lower avg. repetition rate

Note: Femtoslicing not practical at APS (7 GeV) (A. Zholents)

Crabbing scheme†



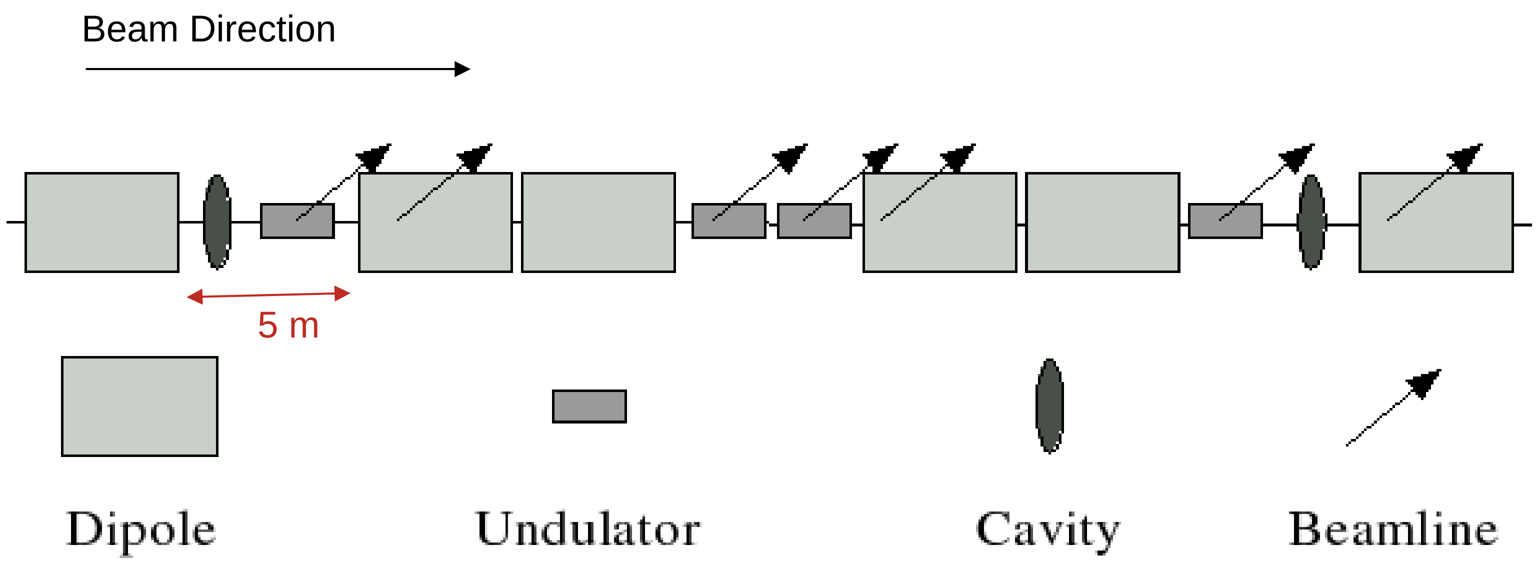
- Deflecting ("crab") cavity operating in TM_{110} mode; B_x kicks head and tail of bunch in opposite directions vertically
- Bunch evolution through lattice results in photons correlated with vertical momentum along the bunch length
- Ultrashort x-ray pulse either using slits or compression optics
- Second crab cavity at appropriate phase cancels kick; rest of storage ring nominally unaffected

† A. Zholents, P. Heimann, M. Zolotorev, J. Byrd, NIM A425 (1999)

Feasibility study

- **Beam dynamics issues (M. Borland, V. Sajaev, A. Zholents)**
  - Emittance growth/compensation
  - Effects of errors
  - Effects of impedance/HOMs (ongoing, AP group)
- **Compression optics (S. Shastri, R. Dejus, D. Mills)**
  - Compression throughput
  - Pulse duration and spot size
  - Energy tunability
- **Superconducting crab cavity issues (G. Waldschmidt, G. Pile, D. Horan, R. Kustom, A. Nassiri)**
  - Design constraints (available space, rf power, available rf amplifiers, HOM/LOM damping)

Implementation at APS



- **Minimum implementation shown: 4 IDs and 2 BMs**
- **Emittance growth compensation allows more sectors: maximum number between deflecting cavities to be studied**

Parameters/constraints

- Goal ~1 ps (FWHM) in crab insertion; no impact elsewhere
- Typical bunch length 40 ps rms (100 ps FWHM) (std. 24-bunch mode; 4.25 mA/bunch)
- Beam dynamics parametric study (M. Borland)
  - $h \geq 4$ (1.4 GHz)
  - Deflecting voltage ≤ 6 MV
- Availability of 100-kW class rf amplifiers limits study to $h = 8$ (2.8 GHz)
- Available insertion length for cavities nominally 2.5 m
- White paper (optics and rf): h=8, 4 MV, x-ray pulse length 2.5 ps (FWHM), transmission efficiency (flux) ~20%

Why do we need SC RF?

Assuming CW operation, power and space reqt's favor SC:

- **RF losses for normal conducting (NC), single cell cavity on the order of 10 MW**
- **RF losses for superconducting (SC) cavity on the order of 25 W (2 K).**

Single-cell vs. multiple-cell SC cavity configurations compared

Project schedule overview: SCRF

Year 1

- begin new construction to house cryostation and rf power system
- order/receive cryostation and cryomodules
- order rf power system
- design rf deflecting cavity / fabricate prototype

Year 2

- complete new construction
- install cryostation / assemble cryomodules
- receive rf power system; begin installation
- test cavity & component prototypes
- fabricate final cavity & components / test
- begin integration of cryomodules/cavities

Year 3

- complete rf power system installation
- complete rf cavity test
- complete integration/assembly cryomodules/rf cavities, test, and install
- commission

Project schedule: optics

- **Suite of beamlines to be determined**
  - Some compressed, others not
  - Optimized for tuning range(s)
- **Upgrades to existing ID beamline(s) include optics, modification of vertical apertures, etc**
- **Not trivial, but likely in line with typical new beamline commissioning timeframe of a few years**

Detailed talks

- **Accelerator physics, beam dynamics**
  M. Borland, V. Sajaev
- **Superconducting rf cavity preliminary design, preliminary LOM/HOM analysis**
  G. Waldschmidt
- **X-ray Optics (afternoon session)**
  S. Shastri