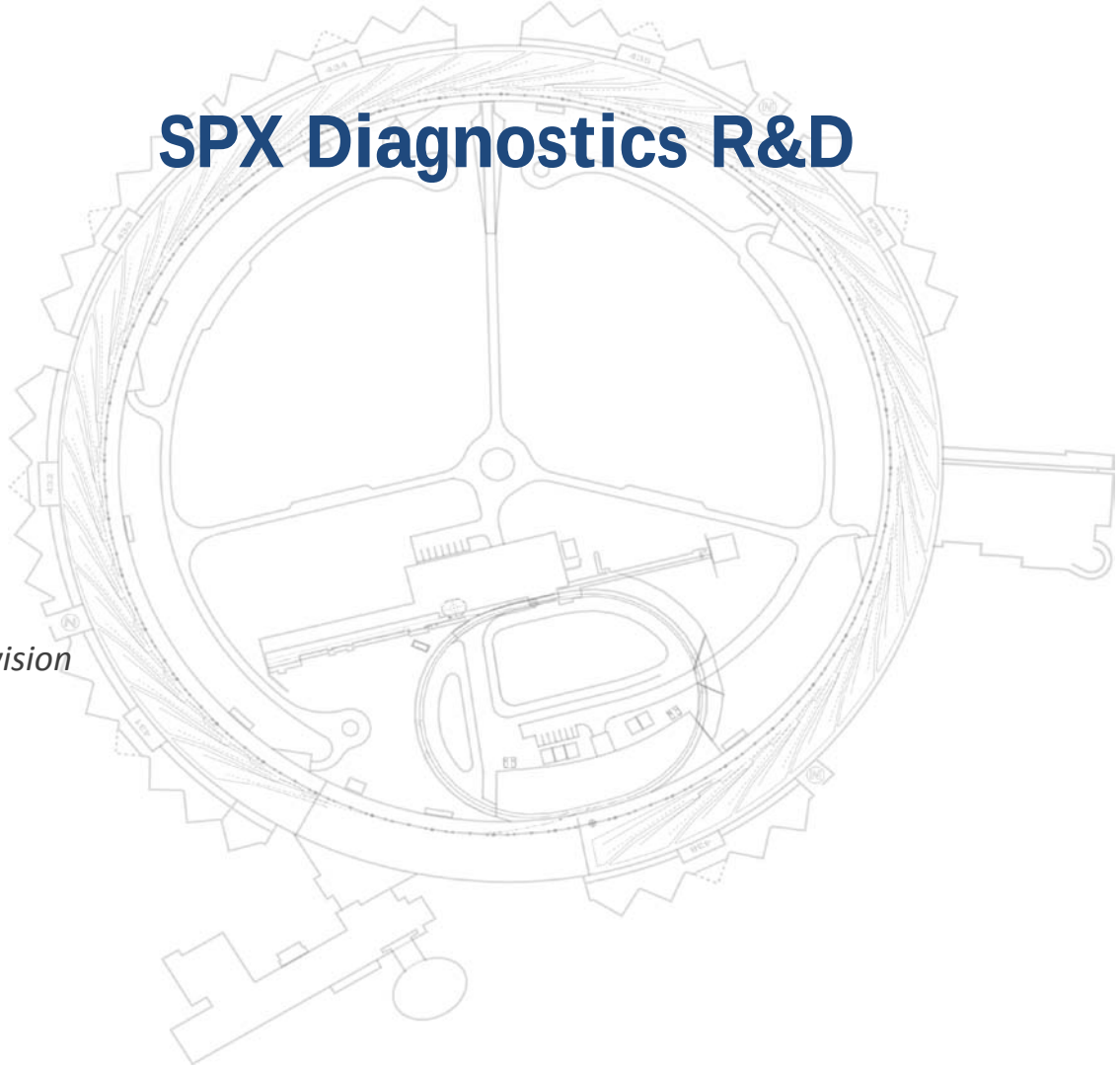
SPX Diagnostics R&D



Glenn Decker

Accelerator Systems Division

SPX Study Meeting
July 18-19, 2011

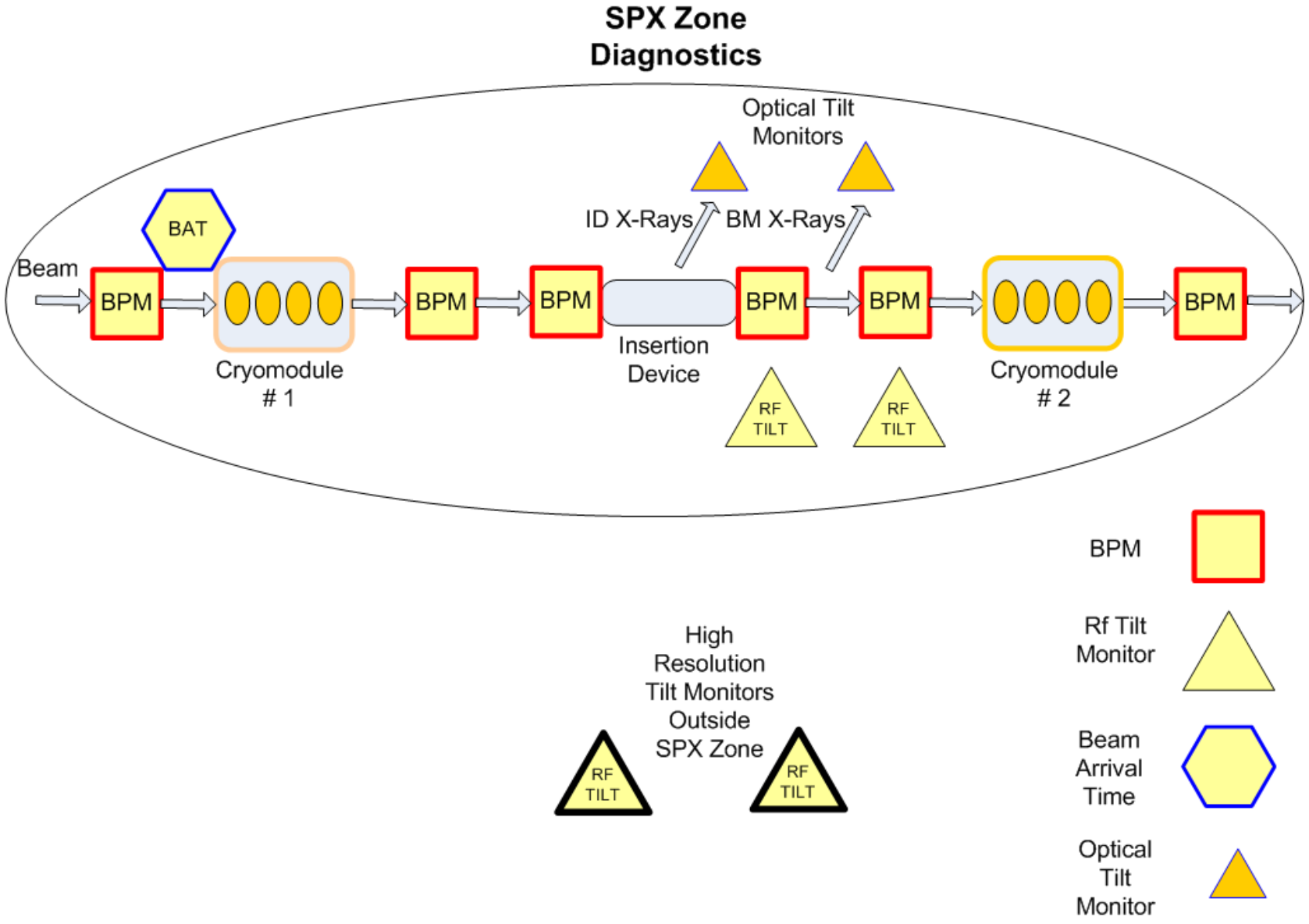
Outline

- Functional Requirements
- Scope of Work
- SPX Diagnostics Overview
- Cavity Tilt Monitor R&D
- Optical Tilt Monitor R&D
- Summary

SPX Diagnostics Functional Requirements

- Measure the beam arrival time with respect to a phase reference and provide this information to low-level rf controls.
  - Beam Arrival Time (BAT) monitor
- Measure the tilt of the electron bunch due to the crab cavities
  - High-resolution RF residual tilt monitors outside crab cavity zone (2)
  - Beam size monitors outside zone (3, proxy for tilt).
  - Optical tilt monitors inside crab cavity zone (2, ID + BM)
  - Low-resolution RF tilt monitors inside crab cavity zone (2)
  - Sector 35 diagnostic beamline for commissioning
    - *Longitudinal, transverse bunch profile*
    - *Streak camera - tilt*
  - Cerenkov detectors / loss monitors – detect stray particles
- Position e-beam through crab cavities and ID source
  - RF Beam Position Monitors

SPX Diagnostics

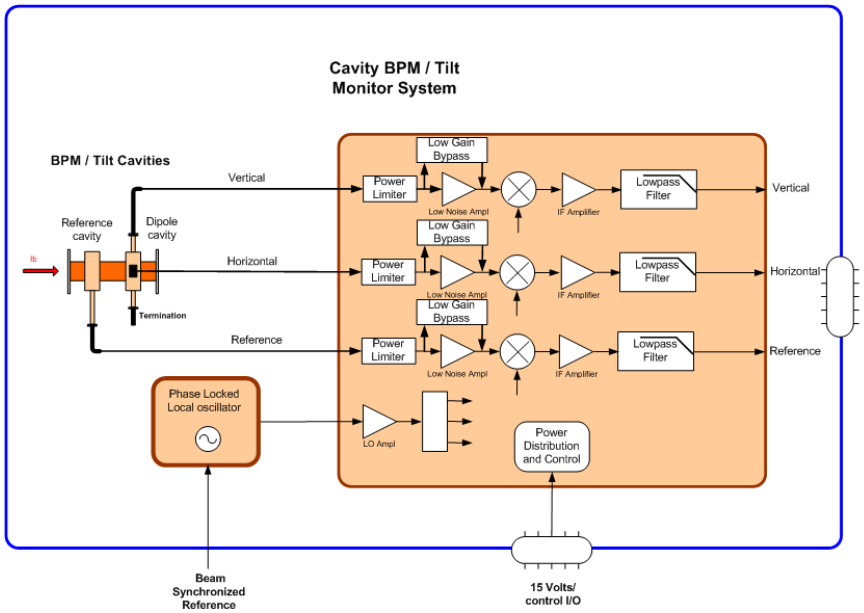


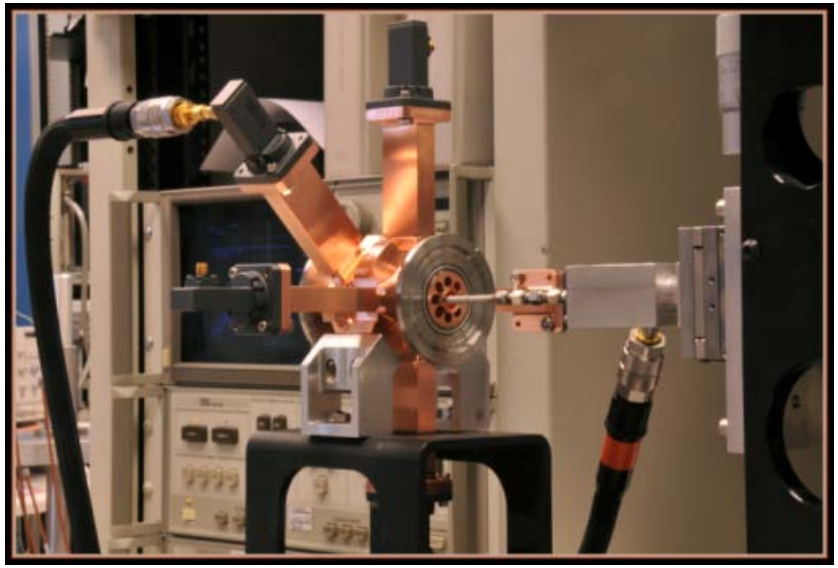
WBS U1.02.01.03.07 SPX Diagnostics R&D

- U1.02.01.03.07.01 RF Tilt Monitor R&D
- U1.02.01.03.07.02 Optical Tilt Monitor R&D
- U1.02.01.03.07.03 Vertical Beam Size Monitor R&D

RF Cavity Tilt Monitor System Design Approach

- Leverage baseline design concepts off LCLS cavity BPM
- Design and build a cold- test prototype cavity-based tilt monitor
- Design and build a receiver prototype
- Evaluate performance and optimize

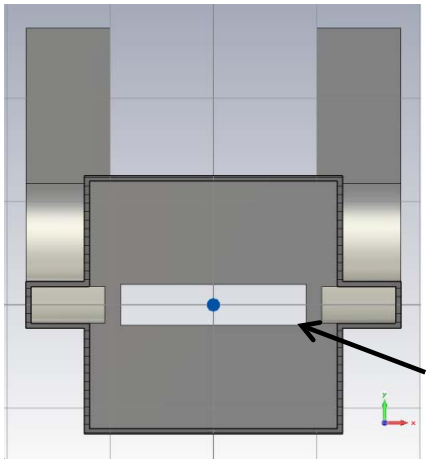


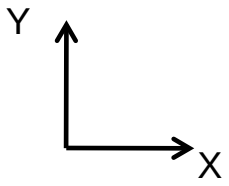


11.26 GHz Square Cavity BPM / Tilt Monitor Pre-conceptual Design

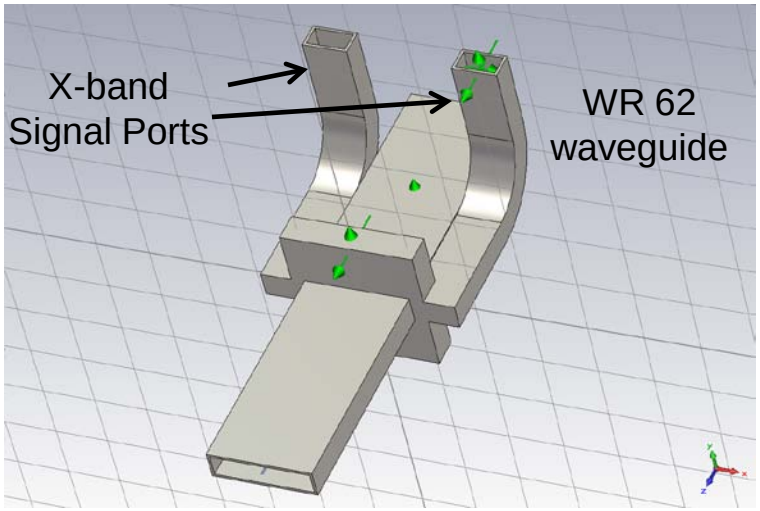
Square cavity concept

46 X 46 X 7.9mm

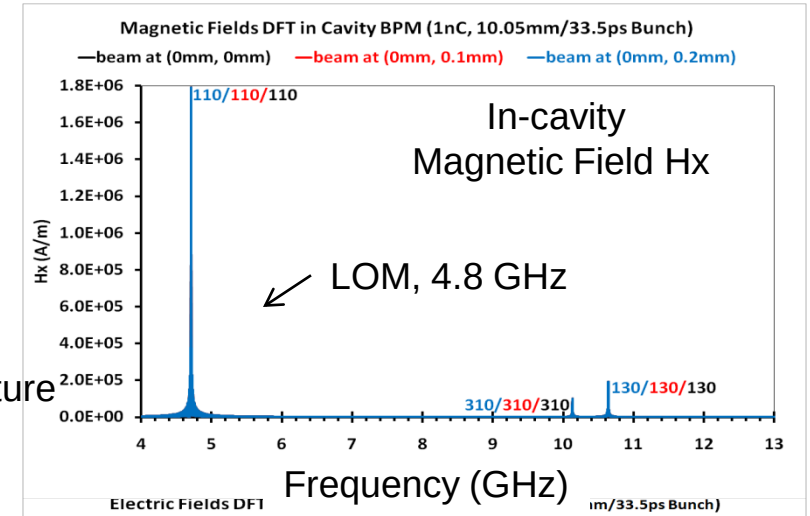


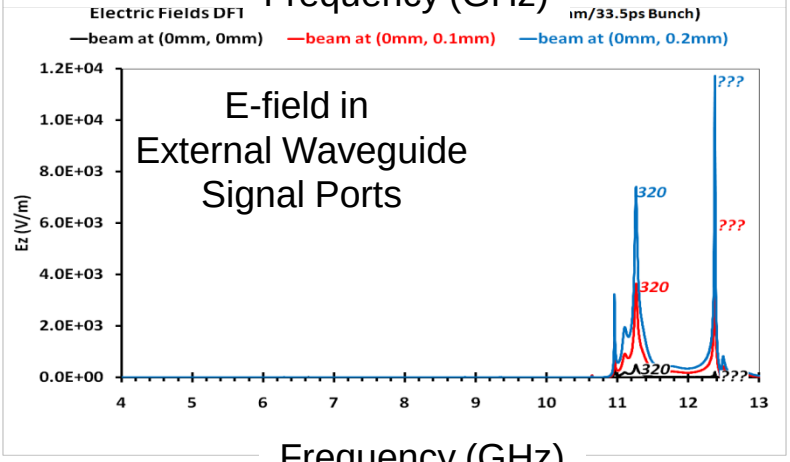


Beam pipe aperture



Magnetic and Electric field simulations





X-ray diagnostics for SPX e-beams: scope

OUTSIDE THE SPX ZONE

(1) **Vertical beam size monitor**

- Minimize disturbance to users outside of the SPX zone
- High-resolution x-ray imaging techniques
- For SPX0, it will be tested with two cavity running with 180-degree phase difference.

INSIDE SPX ZONE

(2) Optical tilt monitor (BM and/or ID)

- Measure x-ray bunch tilt (quantify y-z correlation)
- Visualize density distribution in y-plane, HOM effect, deriving tilt and phase changes
- Measure x-ray bunch arrival time (X-BAT)

(1) High-resolution vertical beam size monitors

- **Motivation and scope:**
  - To obtain shortest SPX x-ray pulse possible, we need to keep the lowest vertical emittance possible.
  - To minimize the disturbance to the users outside of the SPX zone, we need to monitor the vertical beam size at high resolution.
  - Multiple monitors distributed around ring improve speed and reliability of the optimization procedure that minimizes the coupling

- **Basic approach:**
  - Photon sources: high energy x-ray from bend magnets
  - Setup: unused bend magnet beamlines, in-air transport.

- **R&D Plan**
  - Evaluate high resolution x-ray imaging techniques and test most cost-effective approaches.
  - Start surveying literature in FY2011

(2) X-ray tilt monitors (with Bob Lill)

- **Motivation and scope:**
  - To obtain stable x-ray pulse length and arrival time for the SPX users, we need to monitor the x-ray bunch's tilt angle and arrival time.
  - Ideally, each ID / BM beamline should have its own tilt / phase monitor. But the cost is likely to limit our final choices.

- **Basic approach:**
  - Photon sources: x-ray from a bend magnet source
  - Setup: diamond-based x-ray arrival time (X-BAT) monitor array.

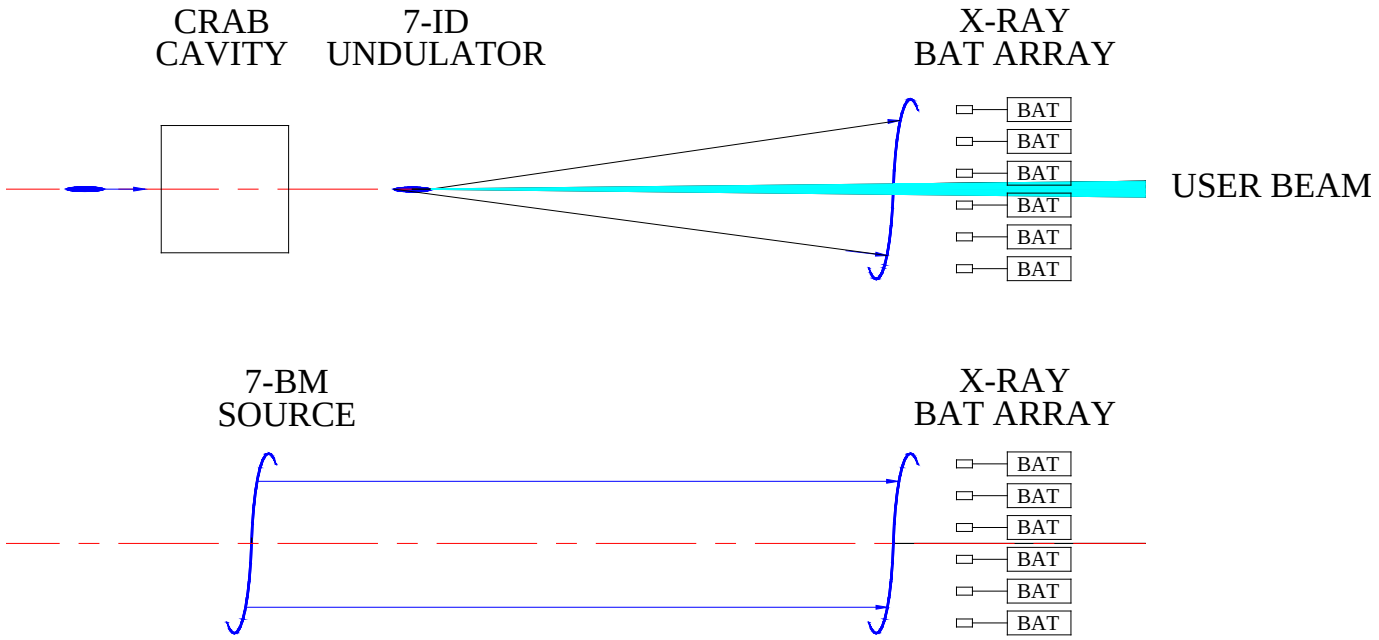
- **Fall-back position:**
  - Imaging vertical x-ray beam profile at bend magnet 6-BM or 7-BM

- **R&D activities**
  - Design and test X-ray Tilt Monitor in FY2011-2013. Install it in FY2013.
  - Progress in FY10-11: Preliminary test successful, measured x-ray bunch phase

X-ray BAT array concept

– In the ID and BM front ends, the x-ray bunches are tilted: The x-ray pulse above the orbit plane arrives earlier than that below the plane. An array of fast x-ray detectors provide signals for the **arrival time** of the x-ray pulses (average) and the **tilt** value of the x-ray photon bunch (difference).

– **Advantage**: Optical measurements are absolute if the geometries are known. Provide real-time monitor for the user x-ray pulses.

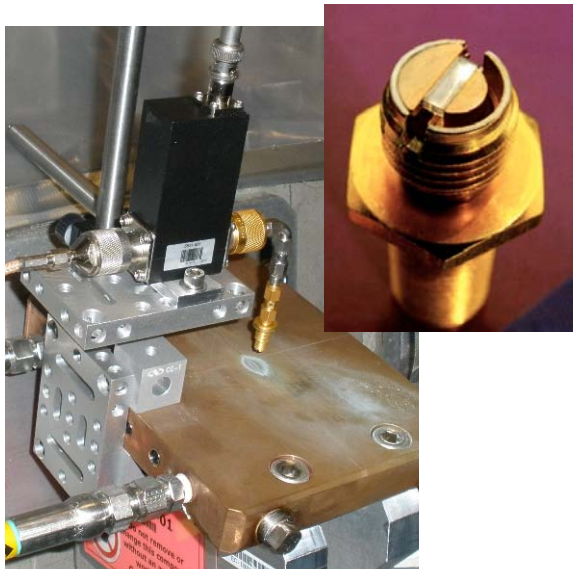


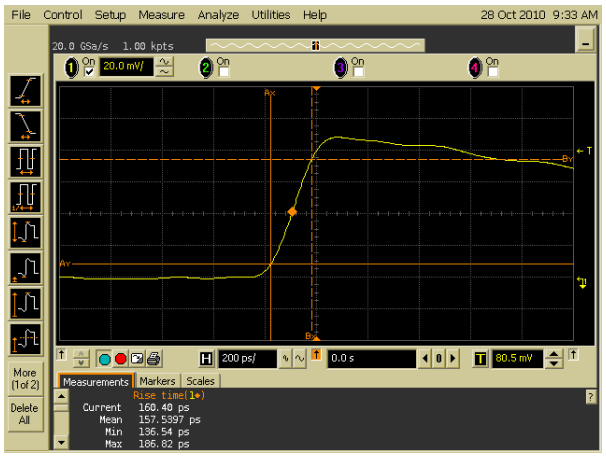
X-ray tilt monitor and BAT monitor R&D (with Bob Lill)

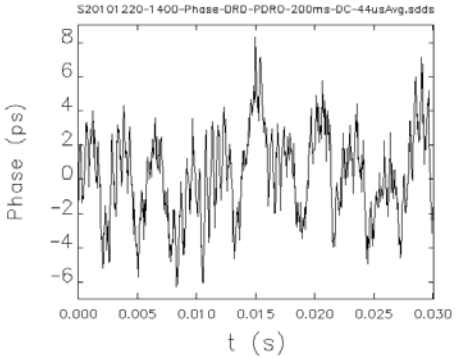
- **X-ray detector is the key component to the BAT array tilt monitor**

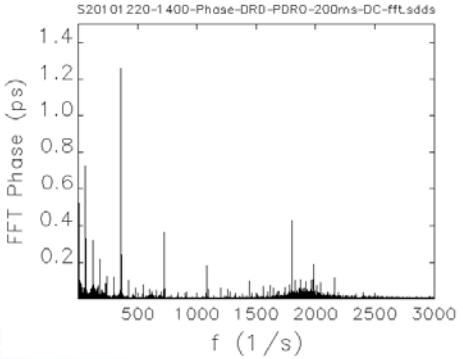
Fast: sub-ns rise time; Rad-hard; Durable; Low time-intensity dependence. Candidate: diamond

- **R&D: Find suitable detector and develop signal processing electronics**
  - Initial test with polycrystalline diamond detector (24 bunch, 35-ID undulator, 5 mm x 5 mm aperture, Cu XRF, peak ~ 80 mV, rise time ~ 160 ps)
  - Initial results for x-ray phase detection against 2815 MHz RF source (8x352MHz PDRO)
  - Next step: Detector = single crystal detector + on-board impedance matching network; Processing electronics: Improve S/N; Built data acquisition.

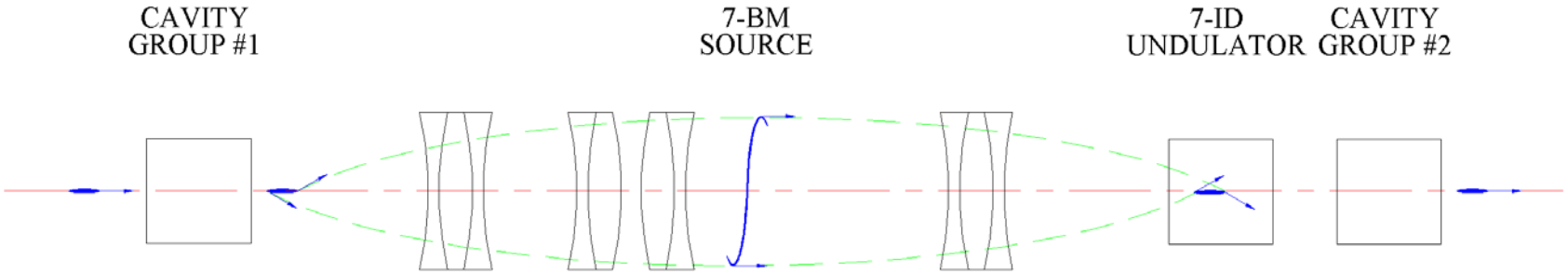




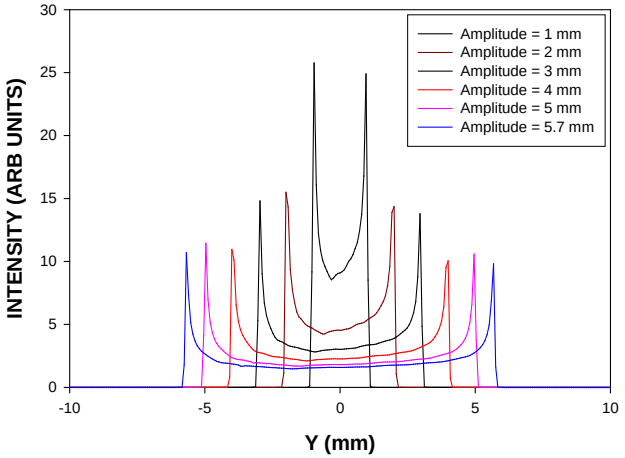




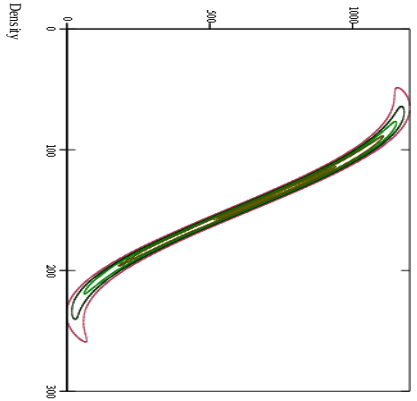
(2-B) Plan-B: vertical beam profile imager



$$\left[\frac{dt}{dy}\right]_{y=0} \approx 20\,ps/mm \;\; @\; 2\;\mathrm{MV}$$



- **Time-averaged image / profile information:**
  - Total tilt ➔ Vertical beam size;
  - RF Phase ➔ Vertical beam centroid;



R & D Plan

- **RF cavity BPM / tilt monitor**
  - Continue modeling studies
  - Construct cold-test model
  - Build prototype receiver electronics
- **Optical tilt – beam arrival time monitor (FY11)**
  - Evaluate fast and robust radiation detectors: diamond (done)
  - Design high-heat-load configuration (in progress)
  - Develop signal processing technique (two BAT differential)
  - Test with APS storage ring / linac beam
- **Vertical beam size monitor (FY11 – FY12)**
  - Evaluate projection / slits optics and other alternatives
  - Build prototypes and test in APS storage ring in unused BM front ends.
  - Develop signal processing techniques.

Summary

- **High-resolution (30 mrad) rf BPM / tilt monitoring is a completely new technology for storage rings**
  - Modeling studies under way.
- **Optical diagnostics are an important alternative for monitoring residual effects**
  - Improvements in resolution and bandwidth of vertical beam size measurements are needed.
- **SPX0 provides an opportunity to implement a number of new technologies**
  - X-BAT array will measure x-ray beam vertical slope and arrival time directly, extracting information about the transverse deflecting cavity operation.