Development of Residual Gas X-ray BPM for PETRA III

Petr Ilinski

DESY/HASYLAB
White undulator beam X-ray BPM

- **Type**
  - Beam halo
    - Blade BPMs
  - Center of gravity of the beam
    - Residual Gas BPMs
    - Diamond BPMs
      - will not work for PETRA III
Background Radiation

Stray Radiation Sources

- Insertion Device
- ID photons
- Main Dipole Bend Magnet
  - 78 mrad
- X-ray BPMs (16, 20 meters from source)
- Positron Trajectory

Legend

- Focusing Quadrupole Magnet
- Defocusing Quadrupole Magnet
- Sextupole Magnet
- Combined Function Horz./Vert. Steering Corrector Magnet

Argonne National Laboratory
Advanced Photon Source

P. Ilinski, DESY/HASYLAB

XFEL-WPG3 meeting, 17.06.08
Allowed to incorporate XBPMs into APS global orbit feedback
ELETRA solution - Electron Energy Analyzer

A. Galimberti, et al. NIM A 467 (2001) 221

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XFEL-WPG3 meeting, 17.06.08
PETRA III

$E = 6 \text{ GeV}, \; I_{\text{max}} = 100 \text{ mA}$
$
\varepsilon \approx 1.0 \text{ nmrad}, \; \kappa = 1\%$
$L_u \approx 2 \text{ m}, 5\text{ m}, 20 \text{ m}$

- 8 new straight sections
- 13 ID beamlines
- 2009 - Start of user operation
Residual Gas X-ray BPM

- **Function**
  - Provide direct, non-destructive measurements of center of gravity of the beam

- **Necessity / Feasibility**
  - Windowless beamlines
  - Differential pumping

- **Spatial resolution**
  - Less then 10 um

- **Reliability**
  - No beam heated components
  - MCP degradation
Residual Gas X-ray BPM
General layout
Spatial Resolution

- **Signal / Noise**
  - Residual gas cross sections
  - Scattering background
- **Quality of the electrical field**
  - Nonuniformity of the electrical field
  - Transverse component of the electrical field
- **Initial kinetic energy of Ions/Electrons**
  - Thermal motion
  - Momentum transfer during the ionization
- **Readout resolution**
  - MCP/Optics/CCD
  - Electronics readout
- **Data processing**
  - Sub-pixel resolution
Signal levels
Signal spatial distribution
Total power

PETRA III undulator 2.9 cm, 2m, K=0.6, Power @ 20 m, 10x10 mm²
Signal level

PETRA III undulator 2.9 cm, 2m, K=0.6, 100 mA
Signal spatial distribution
Mono beam

PETRA III undulator 2.9 cm, 2m, K=0.6, Flux @ 20 m, 20x20 mm²

1 keV 5 keV
PETRA III Generic Beamline

1. granite girder for valves and X-ray BPM
2. primary collimating slit
3. permanent magnet for radiation safety
4. secondary collimating slit and photon shutter
5. bremsstrahlung collimator and beam shutter
6. vacuum diagnostic chamber
7. mirror chamber
8. monochromator
9. bremsstrahlung stop and secondary beam shutter
Design considerations

- Collimation / shielding
- Electrical field quality
- Ionization Cross section
  - choice of gas - N₂
  - residual gas pressure ~ 10⁻⁶ mbar
- Reliability
  - MCP degradation
- Readout
  - Optical readout
    - + Beam Profile
    - resolution vs. FOV
    - slow
  - Split electrode
    - Center of gravity
    - fast, reliable, long electrodes & MCP
  - 1D strip detector (PSI)
    - very fast, no MCP
PETRA III RGXBPM
Canted undulators beamline

Constrain - limited space
Electrostatic/Ion beam propagation Modeling
CST PARTICLE STUDIO
Ion Beam Propagation
RGXBPM for PETRA III
Prototype #3
RGXBPM for PETRA III
Final version
Tests of RGXBPM

- **Test requirements (needs dedicated beamline !)**
  - White undulator beam
  - No windows
  - Adequate scattering background
  - Radiation environment (inside the SR)

- **A number of RGXBPM prototypes were tested**
  - Test stand, e-gun
  - DESY BW3
  - ESRF ID30, ID6
Test Setup

ESRF ID06 03/08, “white” undulator beam, controlled gas environment
Beam Profiles

RGXBPM, 3rd prototype, Optical Readout

ESRF ID06, 300 μm diamond window, undulator u18, gap 9 mm, $E_1 = 16.7$ keV

Exposure time = 500 ms, Optical resolution = 15 μm/pixel
Resolution
RGXBPM 3rd prototype, Optical readout

ESRF 05/2008, ID6, 300 μm diamond, I = 80 mA, u18 gap = 9 mm, E₁ = 16.7 keV, N₂ = 4*10⁻⁶ mbar, RGXBPM vertical scan, step = 10 um
Resolution
RGXBPM 3rd prototype, Electrical readout

ESRF 07/2008, ID6, 300 μm diamond, I = 80 mA, u18 gap=8,10,12 mm
N₂=4*10⁻⁶ mbar, RGXBPM vertical scan

![Graph showing position and current over time with markers for S1, S2 and (S1-S2)/(S1+S2)]
Resolution
RGXBPM 3rd prototype, Electrical readout

ESRF 07/2008, ID6, 300 μm diamond, I = 80 mA, u18 gap=8 mm
RGXBPM vertical scan, step = 20 um

\[
\frac{S1-S2}{S1+S2}
\]
Resolution
RGXBPM 3rd prototype, Optical readout

ESRF ID06 03/08, e-beam refill, u18 gap=9 mm, E1=16.7 keV
300 μm diamond window, N2 = 2.5e-6 mbar
PETRA III Operation
Spatial distribution of undulator radiation, E=1 keV @ 20 m, u29, K=1.2

- 15-mm-diam absorber aperture is located at 16m
- Side electrodes are to detect soft x-ray beam component

P. Ilinski, DESY/HASYLAB
XBPM workshop NSLS II, 25.02.09