Residual Gas X-ray BPM for PETRA III

Petr Ilinski

BNL, NSLS-II
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
Residual Gas X-ray BPM

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

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

- **Spatial resolution**
  - Better then 10 um

- **Reliability**
  - No beam heated components
  - MCP degradation
Residual Gas X-ray BPM
Layout

CCD  L  P  MCP

P  O  I  M  E₁  E₂  R

Beam

Ion trajectories
Spatial Resolution

- **Signal / Noise**
  - Residual gas cross sections
  - Scattering background
- **Quality of the electrical field**
  - Non-uniformity 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

P = 10^{-6} \text{ mBar, } l = 1 \text{ cm}

- N_2 \text{ Ionization Yield}
- H_2 \text{ Ionization Yield}
- N_2 \text{ Photo Yield}
- H_2 \text{ Photo Yield}
- FluxTot_K06_lb_01BW

Electron/photon

Total Flux [ph/s/0.1\%BW]

Energy [keV]
Undulator radiation power density distribution

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

PETRA III undulator 2.9 cm, 2m, K=0.6, 100 mA

![Graph showing signal level for PETRA III undulator with energy range from 0 to 40 keV and flux ranging from 10^14 to 10^8 particles per second per steradian per microwatt.]
Undulator radiation flux density distribution
Signal spatial distribution

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

1 keV

5 keV
PETRA III Generic Beamline

RGX BPMs

QuickTime™ and a (Uncompressed) decompressor are needed to see this picture.
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
Electrostatic Modeling
CST PARTICLE STUDIO

y-transverse component of the electrical field

Center

Edge
Ion Beam Propagation
CST PARTICLE STUDIO
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
  - PETRA-II
  - ESRF ID30, ID6
Test Setup

ESRF ID06 03/2008, “white” undulator beam, controlled gas environment
Beam Profiles
RGXBPM prototype #3, Optical Readout

ESRF 05/2008, ID6, 300 µm diamond window, undulator u18, gap = 9 mm, $E_1=16.7$ keV
$N_2=4\times10^{-6}$ mbar, Exposure time = 500 ms, Optical resolution = $15 \, \mu$m/pixel
Resolution
RGXBPM prototype #3, Optical readout

ESRF 05/2008, ID6, 300 µm diamond window, I=80 mA, u18 gap=9 mm, E₁=16.7 keV
RGXBPM vertical scan, step=10 µm, N₂=4*10⁻⁶ mbar, Exposure time = 500 ms
Resolution
RGXBPM prototype #3, Electrical readout

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

(S1-S2)/(S1+S2)
Resolution
RGXBPM prototype #3, Electrical readout

ESRF 07/2008, ID6, 300-μm-thick diamond window, I=80 mA, u18 gap=8 mm
RGXBPM vertical scan, step=20 um, N₂=4*10⁻⁶ mbar

\[
\frac{(I_1-I_2)}{(I_1+I_2)}
\]

20 um
Resolution
RGXBPM 3rd prototype, Optical readout

ESRF 03/2008, ID06, e-beam refill, u18 gap=9 mm, E1=16.7 keV
Injection, 300 µm diamond window, N₂ = 2.5*10⁻⁶ mbar
Installation at PETRA III
Spatial distribution of undulator radiation, \( E=1\text{ keV} @ 20\text{ m} \), \( u_{29}, K=1.2 \)

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

- **Pros**
  - RGXBPMs may be effective monitors for undulators with complex radiation distribution, such as elliptical undulators
  - soft x-ray insertion devices

- **Cons**
  - sensitive to halo of undulator radiation
  - expensive
  - MCP degradation

- **Residual gas XPBM may be sensitive to:**
  - jumps of gas pressure
  - MCP gain non-uniformity
  - instability of the HV power supplies

- **Further studies of RGXBPMs have to be performed in order to ensure reliable operation**
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