First Vibrating Wire Monitor Measurements of a Hard X-ray Undulator Beam at the Advanced Photon Source

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• Device Description
• Experiment Description
• Experiment Results
• Conclusions
Vibrating wire monitor as tested

- Photon Beam
- VWM Aperture
View along x-ray beam direction

Stainless Steel Wires

5 mm Dia.

14 mm

1.7 mm

10.4 mm

58.2 mm
1. VWM Base
2. Vibrating wires
3, 4, 5. Fastening Parts
6. Fastening Plate
7. Contact Plate
8. Soldering Surfaces
9. Screw
10. Permanent magnet
11. Magnet poles
12. VWM mounting screw
\[ \Delta T_{\text{max}} = -4 \frac{f - f_0}{f_0 E \alpha_S} \sigma_0; \quad \sigma_0 = f_0^2 L^2 \rho \]

- \( f - f_0 \) = Frequency shift
- \( L = \) wire length = 3.6 cm
- \( E = \) modulus of elasticity = 2e11 Pa, stainless steel
- \( \alpha_S = \) thermal expansion coefficient = 1.75e-5 K\(^{-1}\)
- \( \sigma_0 = \) initial wire stress
- \( \rho = \) wire density = 8e3 kg / m\(^3\)
Plan View of VWM@APS Experimental Arrangement

E = 7 GeV
I_b = 4.5 mA
APS Undulator type A,
Gap = 45 - 80 mm
(normal range 11 - 30 mm)

# Power levels for APS Undulator A

<table>
<thead>
<tr>
<th>Undulator gap, cm</th>
<th>$B_0$, T</th>
<th>$P_T$ for 100 mA, W</th>
<th>$P_T$ for 4.45 mA, W</th>
<th>$P_T$ after 7 mm filter, W*</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.00E+00</td>
<td>9.02E-04</td>
<td>5.99E-03</td>
<td>2.67E-04</td>
<td>7.31E-05</td>
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<td>1.59E-02</td>
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<td>1.81E-01</td>
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<tr>
<td>2.90E+00</td>
<td>1.31E-01</td>
<td>1.27E+02</td>
<td>5.67E+00</td>
<td>1.55E+00</td>
</tr>
</tbody>
</table>

* Beryllium mass absorption coefficient = 1 cm² / g @ 10 keV
Vertical Antisymmetric 4-bump

27.6 meters APS sector length

7.5 mm

Insertion Device Vacuum Chamber
Vertical local bump scan, 5 µrad steps

Undulator Gap = 60 mm

Elapsed Time (Hr)

$\Delta T_C, \Delta T_D$ (K)

$\Delta T_C - \Delta T_D$

5 µm

Shutter Opened
\[ \Delta T_C, \Delta T_D (K) \]

Vertical Position (mm)

Vertical Position, (Shifted for \( \Delta T_D \)) (mm)
Conclusions

- Vibrating wire monitor is well-suited to neutral beams such as x-rays
- Device is sensitive at the level of tens of nanowatts.
- Resolution is at the level of +/- 0.001 K
- Long-term differential drift (hours) is < .01 K.
- Time constant in-vacuum is quite long - 30 seconds as tested, however,
  See S. Arutunian, “Transition Thermal Processes in Vibrating Wire Monitors”, session WEPB
  Placement in air increases bandwidth considerably, at the cost of sensitivity, e.g. B.K. Scheidt, DIPAC 2005
- Implementation as an x-ray beam position monitor looks promising.
A very successful shift