Nanoradian Angular Stabilization of X-ray Optical Components

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Outline

- Stabilization of high resolution x-ray optics.
- Automatic adjustment of Bragg angle: principle of operation
- Implementation at Sector 30
- Performance
- Operation
- Conclusions
Motivation: feasibility studies of XFELO

Precise control of the cavity geometry is needed

Design Requirements:
- Angular stability - $\delta \Theta \lesssim 10$ nrad
- Feedback on the signal of interest - the XFELO output
- Stabilization of multiple optical axes using one common detector

High Resolution X-ray Optics

A similar problem: stable operation of the state of the art high resolution optics at the 3rd generation synchrotron sources

<table>
<thead>
<tr>
<th></th>
<th>C(111) cooled monochromator</th>
<th>high-resolution monochromator 23.74 keV</th>
<th>KB focusing mirror</th>
</tr>
</thead>
<tbody>
<tr>
<td>bandwidth</td>
<td>≈100 eV</td>
<td>≈0.9 meV</td>
<td>focus 5 μm ×40 μm</td>
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<td></td>
<td>1×10^{13} Hz @ 23.74 keV</td>
<td>2×10^9 Hz</td>
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</tbody>
</table>

HERIX @ 30-ID

9 detectors

9 analyzers
Variation in x-ray intensity due to modulation with $v(t)$: $I(t) \simeq R(V_0) + \frac{dR}{dV}(V_0)v(t)$

For a quadratic profile of the rocking curve, $R(V) = R_{max} - B(V - V_{max})^2$,

the derivative is proportional to deviation from the optimal voltage $V_{max}$: $\frac{dR}{dV}(V) = -2B(V - V_{max})$

The amplitude of $I(t)$ is extracted by demodulation (lock-in detection) and used to form a correction signal.
Feedback implementation

Lock-in amplifier (SR830)

Integrator (built in-house)

Nanoradian angular stabilization, S. Stoupin, InterCAT TWG Meeting, Aug 20, 2009
Feedback implementation: C(111) high heat load mono

Inside the mono: 1\textsuperscript{st} crystal

Piezo driver (Queensgate AX101)

- first resonance at \(\approx 16\) Hz
- inherent servo loop at 30-70 Hz

Feedback loop is operated with ref. oscillator frequency of 2 Hz
Feedback implementation: 6 bounce high resolution mono

T. Toellner et al., $\Delta E \simeq 0.9\text{ meV} \, @\, 23.725\text{ keV}$

Feedback loop is operated on the $3^{rd}$ pair (crystals 5 and 6) using ref. oscillator frequency of 10 Hz
Angular stability of the 3rd pair

Voltage to angle conversion factor: $\gamma \simeq 7 \mu \text{rad/Volt}$

Reliable operation of the feedback is achieved with 4-6 mV amplitude of the ref. oscillator $\rightarrow$ 50 nrad angular fluctuations
The output intensity (green) is tracking an input x-ray intensity on the 3rd pair (red) while the correction signal (brown) drifts slowly to provide compensation.

The large peak in the correction signal - refill of liquid N\textsubscript{2} for the 2nd pair: the output intensity remains stable.
Operation

- two feedback channels
- remotely controlled (EPICS, SPEC)
- now employed in user operations
Summary

- ≈ 50 nrad stability is demonstrated
- the old simple technique is applicable to high resolution optics
- substantial improvement in beamline performance
- encouraging first step towards stabilization of the XFEL O cavity

Future work:

- demonstrate 10 nrad stability
- development of a multi-channel feedback system
- stabilization of multiple optical axes using one common detector
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