Vibrational Stability of a Cryocooled Horizontal-Bounce Double Crystal Monochromator

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Two years ago in Melbourne...

- A vibrational number is pointless without a physical frequency range.
- Relative pitch level of DCM 48 nrad RMS, 1-2500 Hz (and 17 nrad RMS over 2 – 100 Hz)

If this vertical vibration is too much

one solution

Horizontal DCM
HDCM functionality

Energy range Si111: 5 – 30 keV
Constant horizontal offset: 10 mm

<table>
<thead>
<tr>
<th>Motion</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bragg rotation, $R_{X_{\text{Bragg}}}$</td>
<td>26°</td>
</tr>
<tr>
<td>Bragg mount lateral, $Z_{\text{Bragg}}$</td>
<td>6 mm</td>
</tr>
<tr>
<td>Second crystal pitch, $R_{X'}$</td>
<td>2°</td>
</tr>
<tr>
<td>Second crystal roll, $R_{Y'}$</td>
<td>2°</td>
</tr>
<tr>
<td>Second crystal perpendicular, $Z'$</td>
<td>3 mm</td>
</tr>
</tbody>
</table>
HDCM, NanoMAX at MAX IV
Measurement setup

NXC NanoSensor from Queensgate, 0.1 nm at 5000 Hz
Measurement setup
Relative pitch vibration

Relative pitch, 1-2500 Hz, 5.9 bar

- [Hz]; [kW]
  - 30; 3.0 (Avg. 64, Sdev. 16)
  - 20; 2.0 (Avg. 36, Sdev. 8.6)
  - 15; 1.5 (Avg. 25, Sdev. 2.1)

RMS [nrad]

Bragg [°]
Available cooling power

\[ E(V, T_{\text{Pot}}) = V \rho_{\text{LN2}} C_{\text{LN2}} T_{\text{Pot}} \]

\( V \) is flow rate, \( \rho \) is density, \( C \) is heat capacity and \( T_{\text{Pot}} \) is the difference in temperature between the LN2 sacrificial cooling bath of the cryocooler, 77 K, and the boiling temperature of the circulating LN2, e.g. 18 K at 5.9.
Relative pitch, 1-2500 Hz

- [bar] ; [Hz]
  - Red: 1.0 ; 25, 35, 45
  - Grey: 2.0 ; 20, 30, 40
  - Green: 4.0 ; 15, 20, 30
  - Blue: 5.9 ; 15, 20, 30

Avg. RMS [hrad]

- E [W]
  - 0 500 1000 1500 2000 2500 3000
Absolute pitch, 2-2500 Hz

120 nrad RMS at 10.15°
(11.22 keV)

7 meV RMS
offset change 0.2 nm RMS.
Relative vs absolute vibrations

Vibrations at 5.9 bar cryopressure

Relative @ 10° [mrad]

Absolute @ 9° [mrad]

Hz

3034 W

2023 W

1517 W
Internal cryo support – absolute vibration
Crystal vs Cryo Support Vibration

Bragg angle:
- 25°: turquoise dashed line
- 20°: purple line
- 15°: grey dashed line
- 10°: blue line
- 5°: red dashed line
- 0°: green dashed line

RMS vibration [nm]

Cut frequency [Hz] from 0 to 350 Hz

Solid line = Crystal
Dotted line = Cryo support

Vibrometer

0°, 26°, 1st, 2nd
Integrated PSD with 5.9 bar cryopressure

Bragg angle
- 25°
- 20°
- 15°
- 10°
- 5°
- 0°

RMS @ 30 Hz [nrad]
RMS @ 20 Hz [nrad]
RMS @ 15 Hz [nrad]

Cut frequency [Hz]
Conclusions

• Relative horizontal pitch stability **25 nrad RMS, 1 – 2500 Hz**, at $E_{\text{pot}} = 1500$ W

• More rigidity is not always better – frequency band considerations needed

• Lowering the flow rate reduces vibration $\rightarrow$ higher pressures needed...

Outlook

• Re-design/dimensioning of the in-vacuum LN flow path

• Higher pressure of the circulating LN
Will there be enough flow..?

500 W → 1.2 L/min at 12 bar →

Re = 3380
h = 1640 W/(m² C)

Temperature rise across the boundary layer = 27 K
Questions?

Vibrational stability of a cryocooled horizontal double-crystal monochromator

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The vibrational stability of a horizontally deflecting double-crystal monochromator (HDCM) is investigated. Inherently a HDCM will preserve the vertical beam stability better than a ‘normal’ vertical double-crystal monochromator as the vibrations of a HDCM will almost exclusively affect the horizontal stability. Here both the relative pitch vibration between the first and second crystal and the absolute pitch vibration of the second crystal are measured. All reported measurements are obtained under active cooling by means of flowing liquid nitrogen (LN₂). It is found that it is favorable to circulate the LN₂ at high pressures and low flow rates (up to 5.9 bar and down to 3 l min⁻¹ is tested) to attain low vibrations. An absolute pitch stability of the second crystal of 18 nrad RMS, 2–2500 Hz, and a relative pitch stability between the two crystals of 25 nrad RMS, 1–2500 Hz, is obtained under crycooling conditions that allow for 1516 W to be adsorbed by the LN₂ before it vaporizes.