Vibrational Stability of a Cryocooled Horizontal-Bounce Double Crystal Monochromator

MEDSI 2016

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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

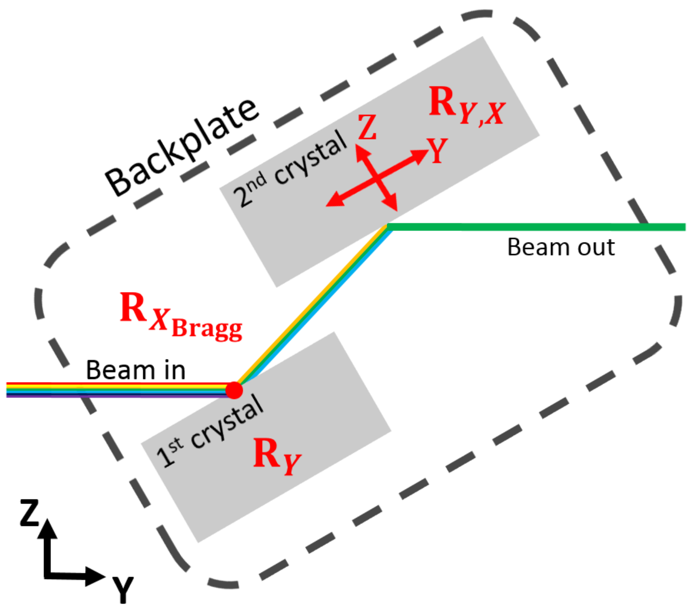
↓ one solution

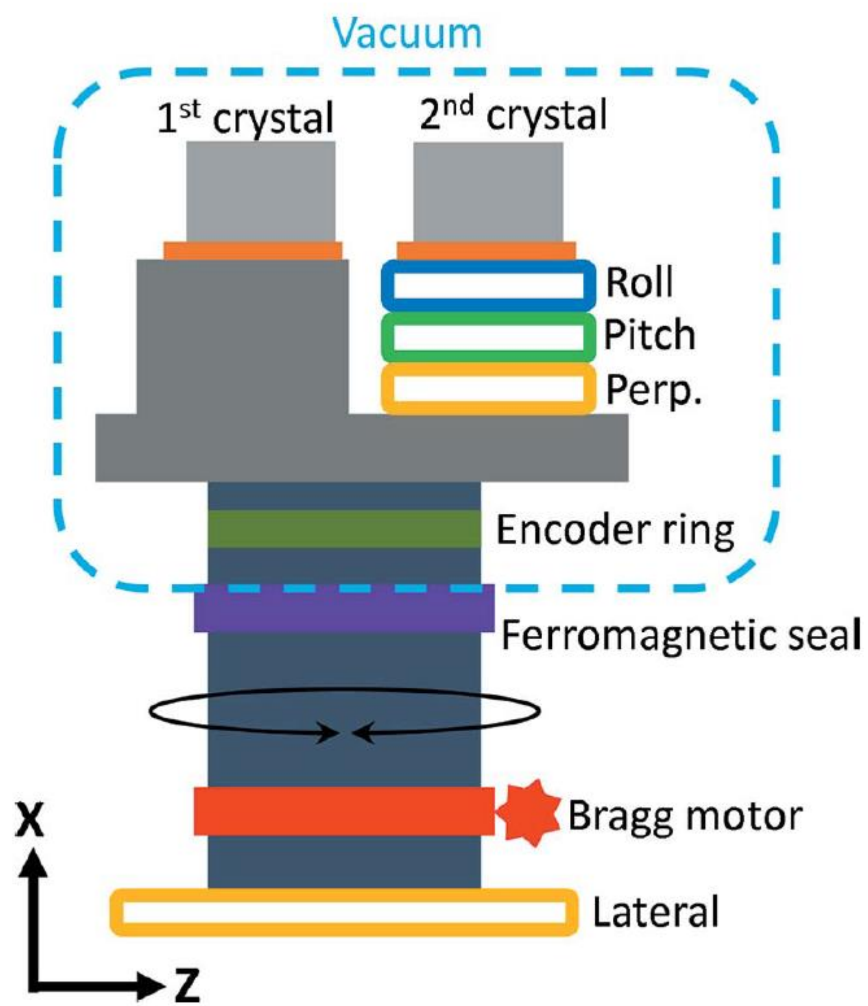
Horizontal DCM

HDCM functionality

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

Motion	Range
Bragg rotation, $R_{X\,\mathrm{Bragg}}$	26°
Bragg mount lateral, Z_{Bragg}	6 mm
Second crystal pitch, $R_{X'}$	2°
Second crystal roll, $R_{Y'}$	2°
Second crystal perpendicular, Z'	3 mm

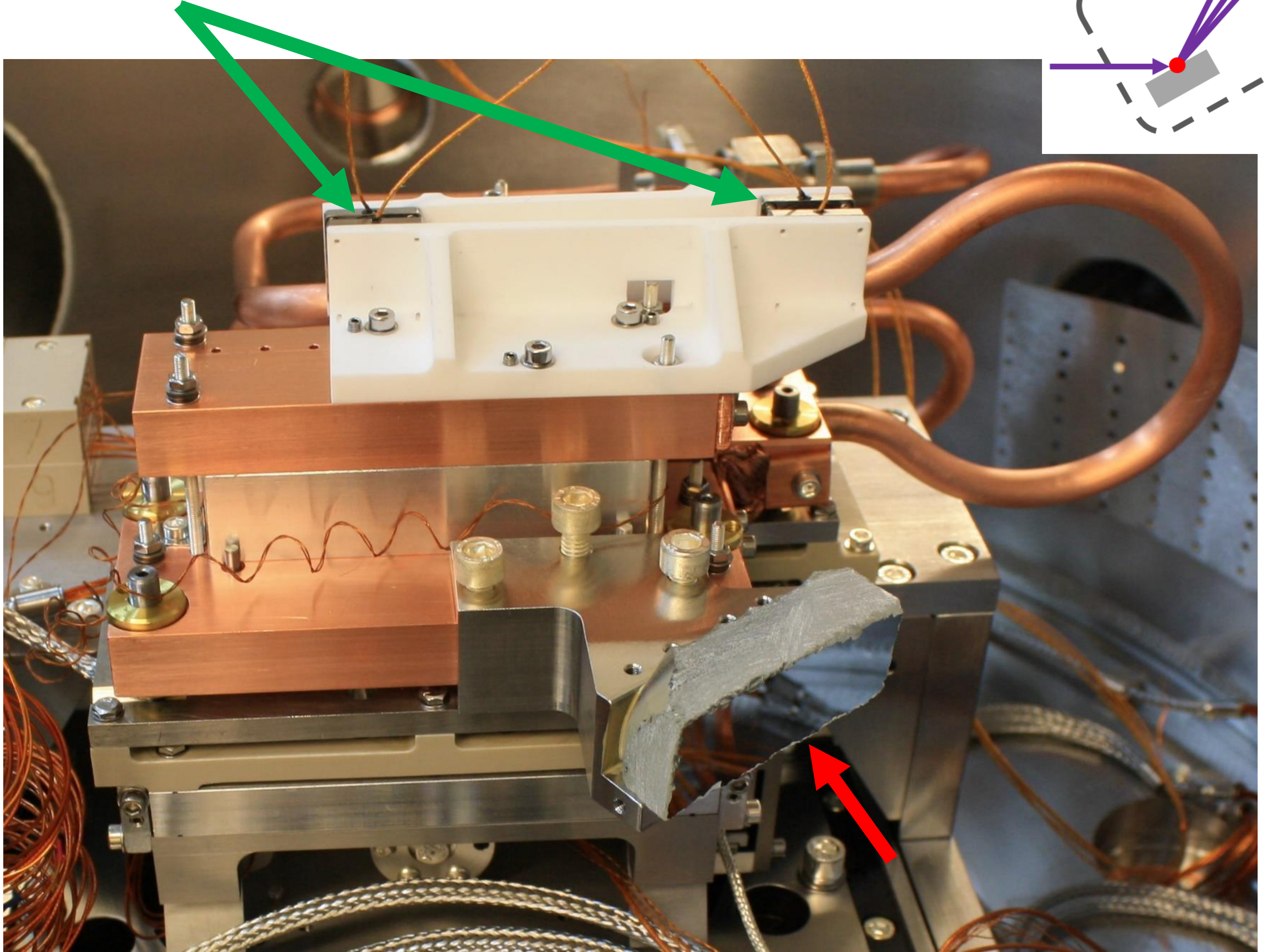


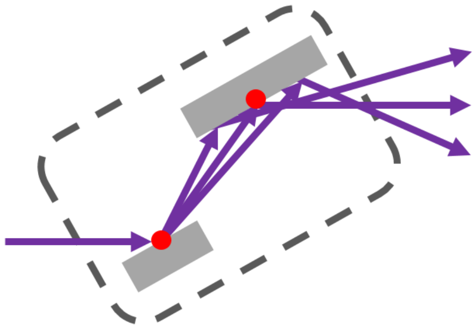


HDCM, NanoMAX at MAX IV

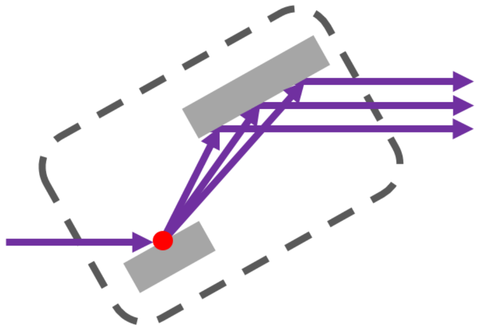
Measurement setup

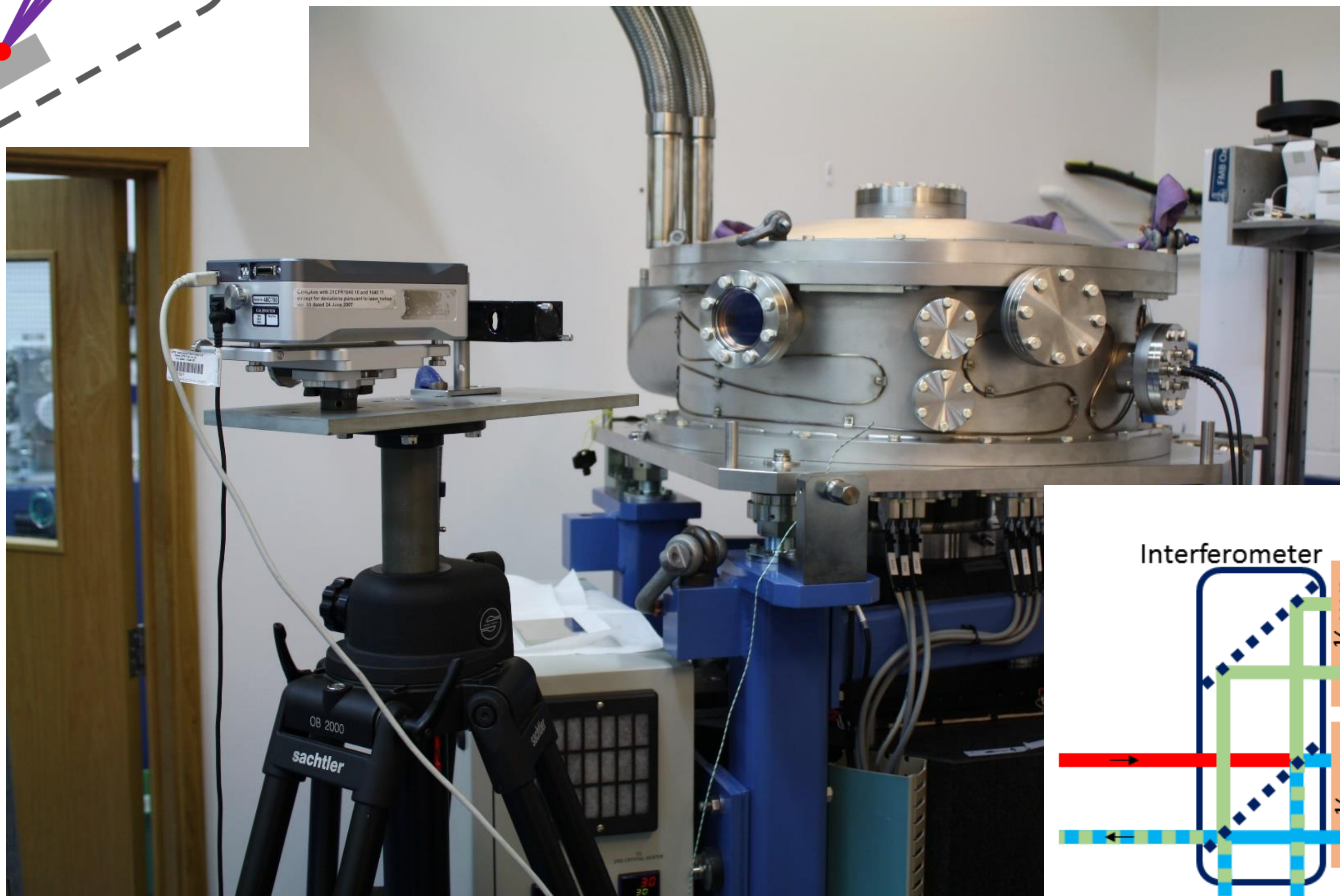
NXC NanoSensor from Queensgate, 0.1 nm at 5000 Hz

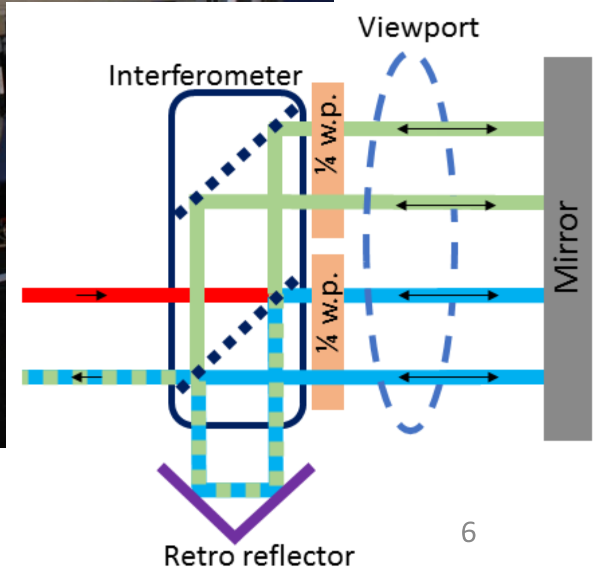




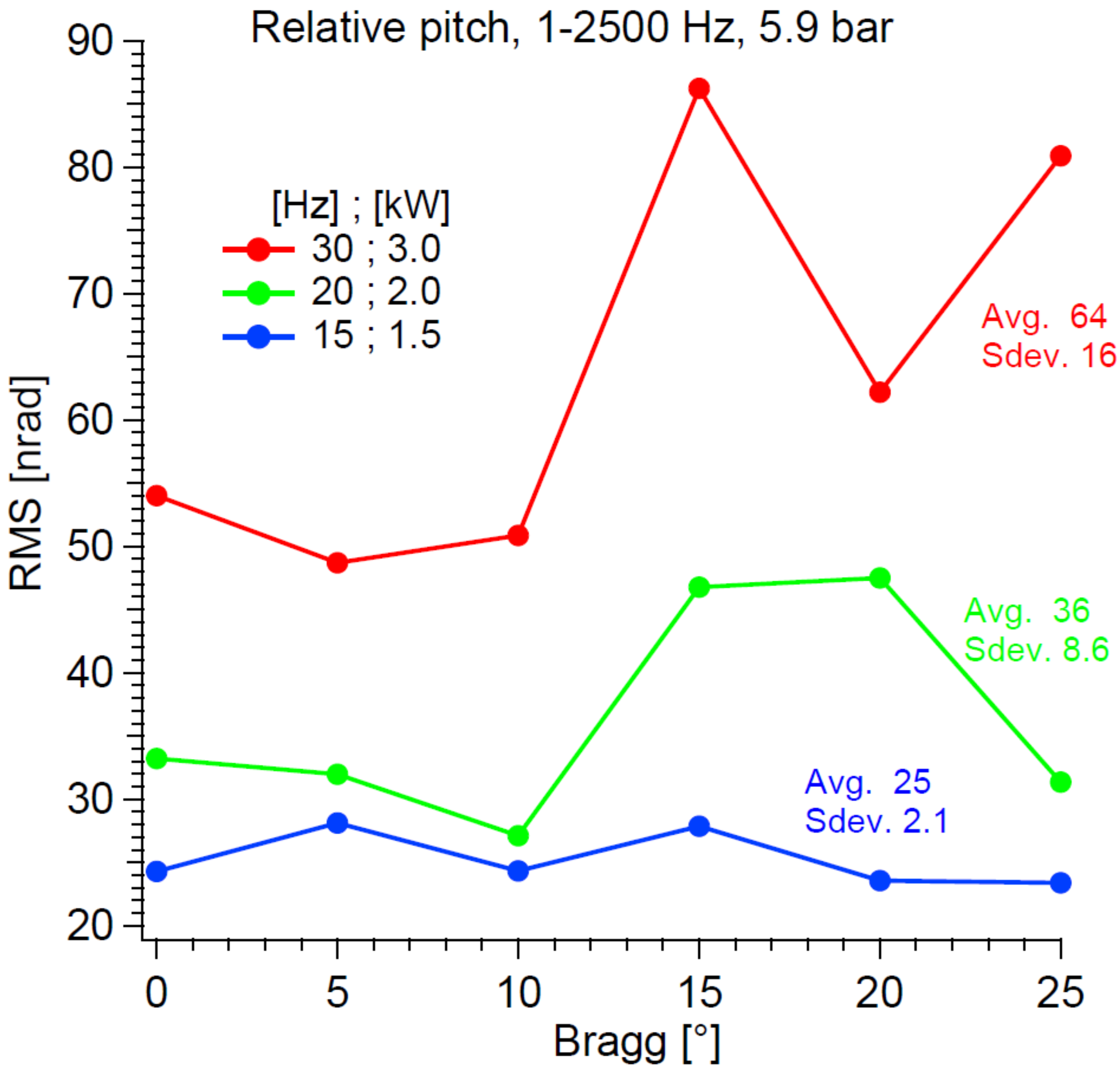
Measurement setup







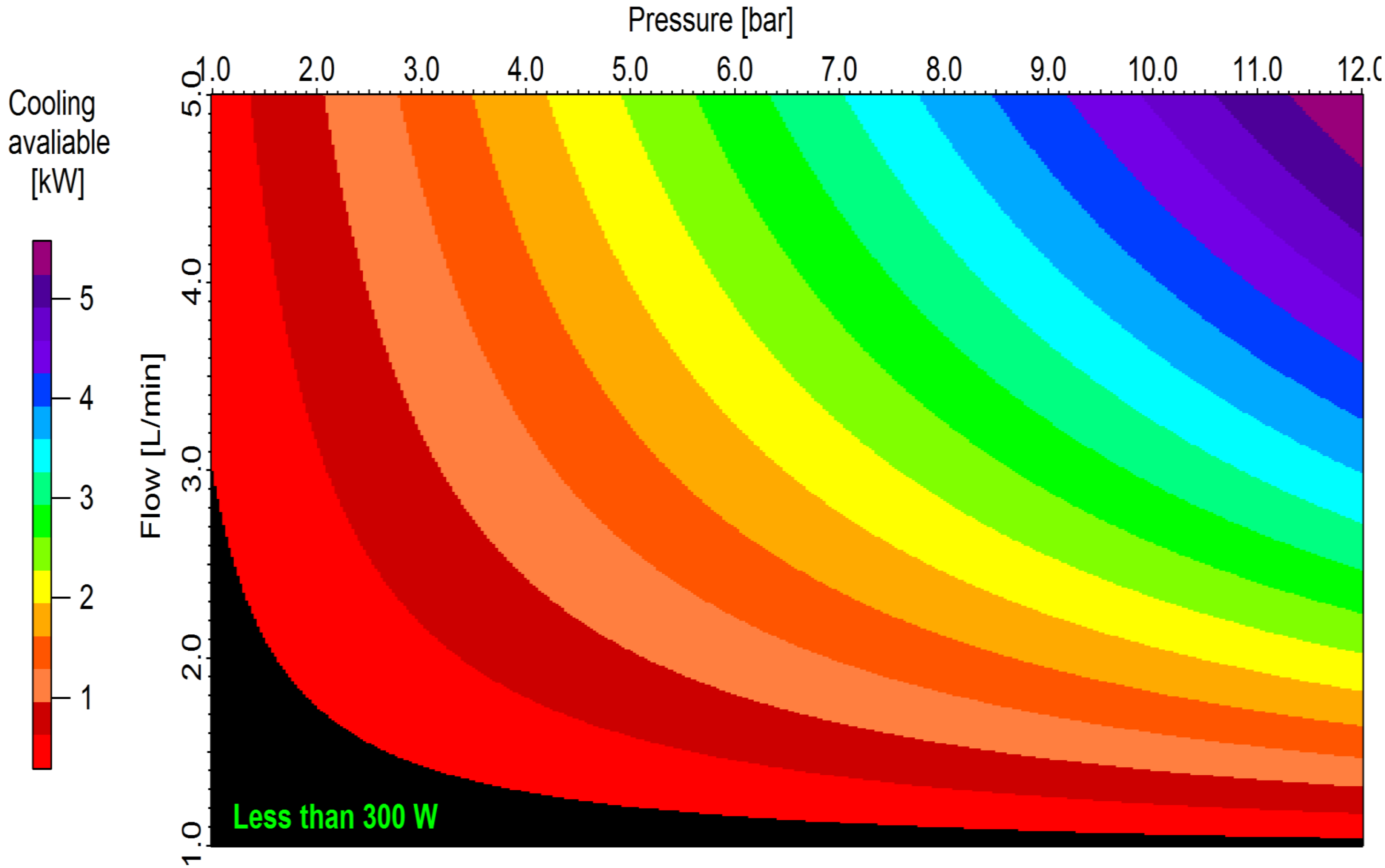
Relative pitch vibration

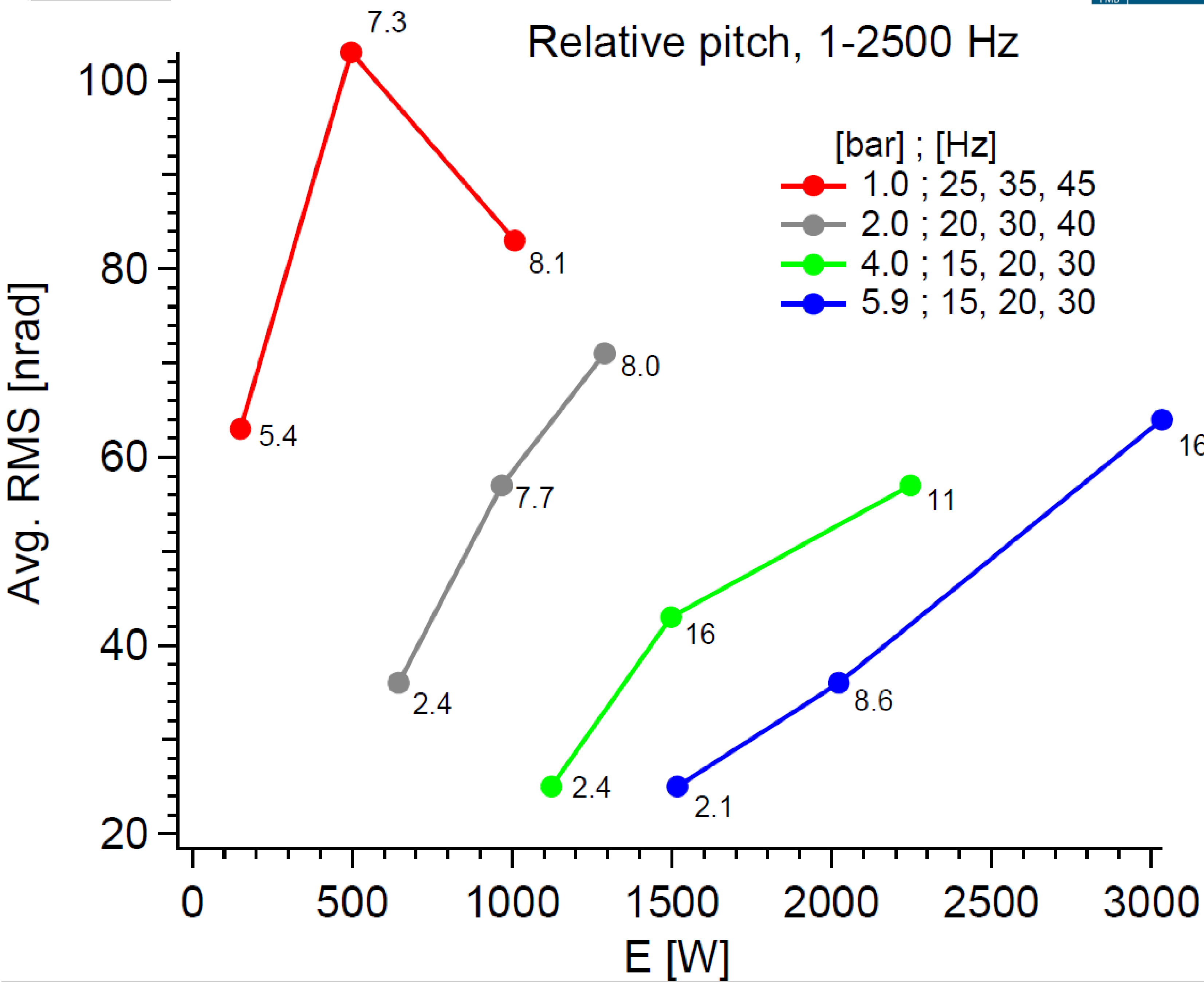


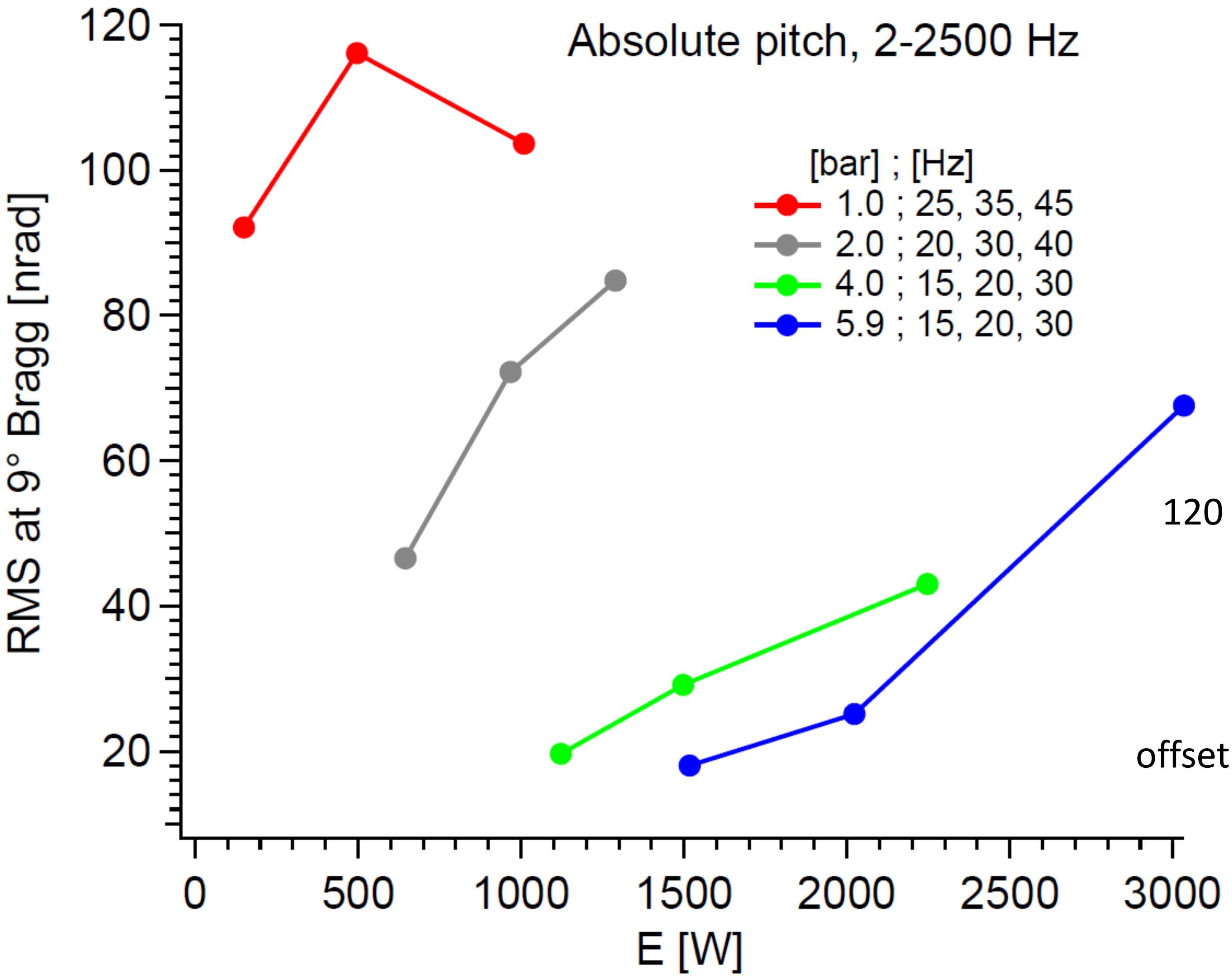
Available cooling power

$$E(V, T_{\mathrm{Pot}}) = V\, \rho_{\mathrm{LN2}}\, C_{\mathrm{LN2}}\, T_{\mathrm{Pot}}$$

V is flow rate, ρ is density, C is heat capacity and T_{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
Avg. RMS [nrad]
E [W]
[bar] ; [Hz]
1.0 ; 25, 35, 45
2.0 ; 20, 30, 40
4.0 ; 15, 20, 30
5.9 ; 15, 20, 30
7.3
8.1
5.4
8.0
7.7
2.4
11
16
2.4
16
8.6
2.1
100
80
60
40
20
0
500
1000
1500
2000
2500
3000

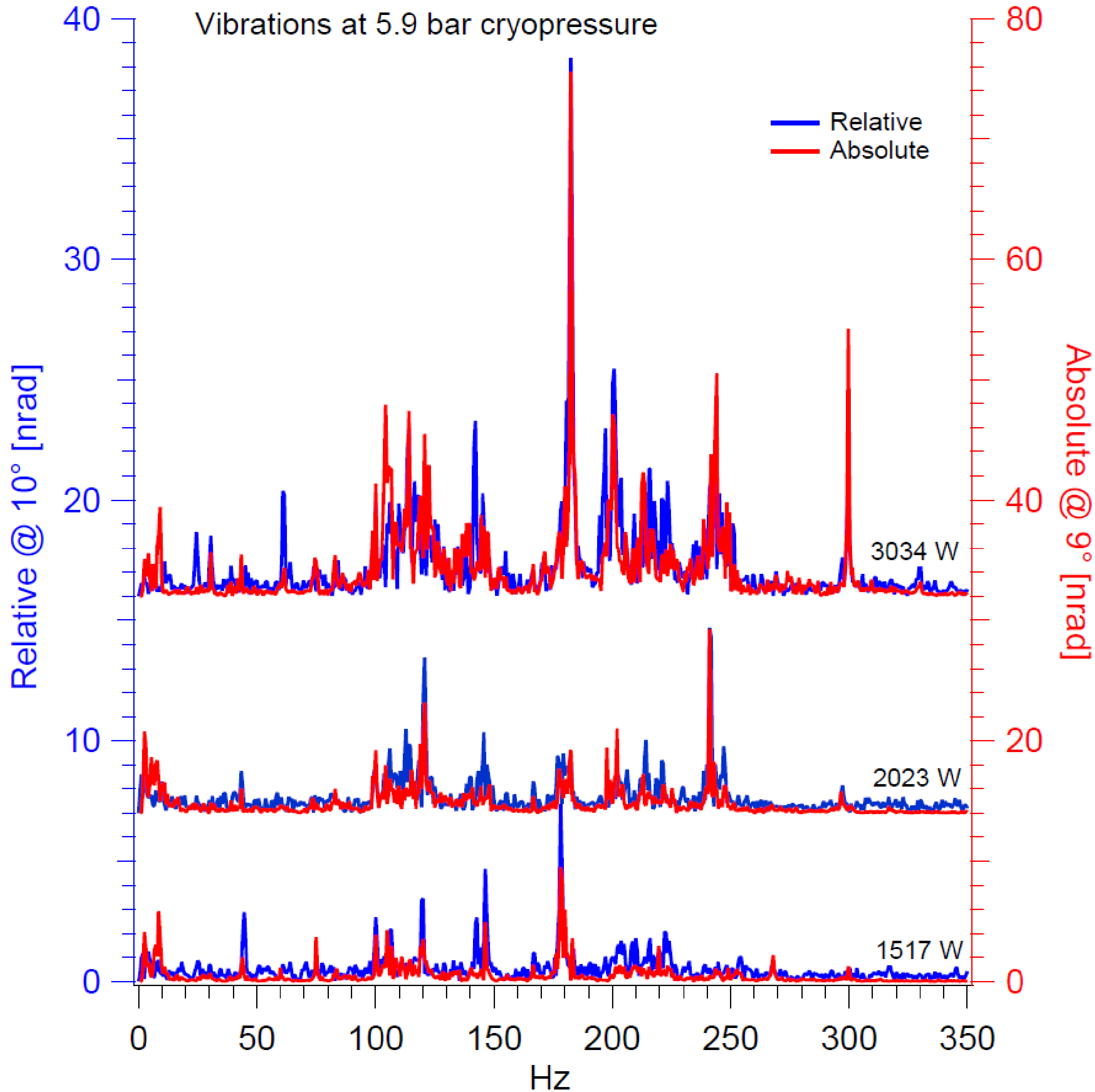


120 nrad RMS at 10.15°
(11.22 keV)

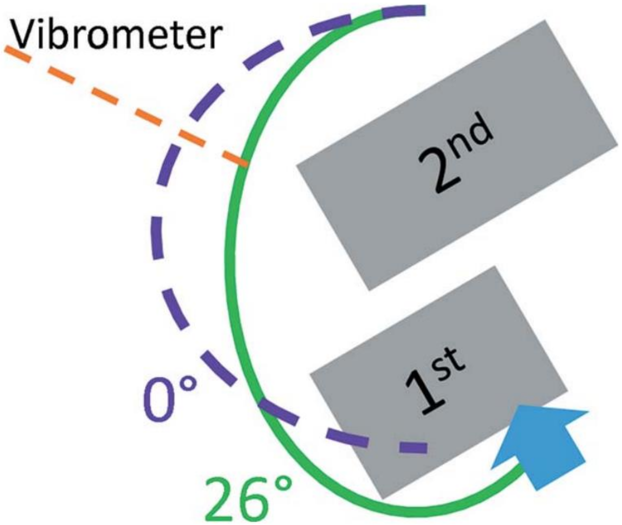
↓

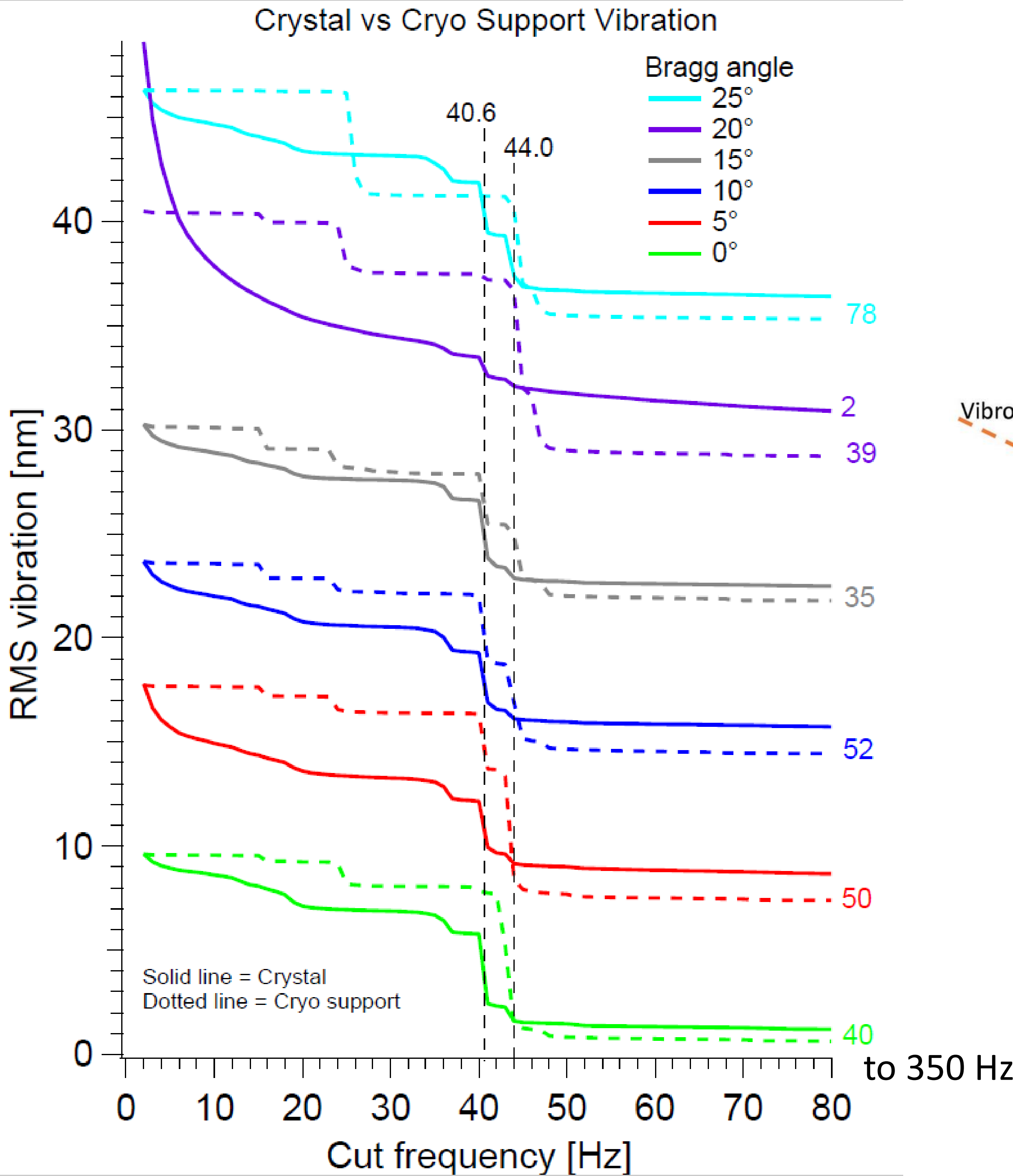
7 meV RMS
offset change 0.2 nm RMS.

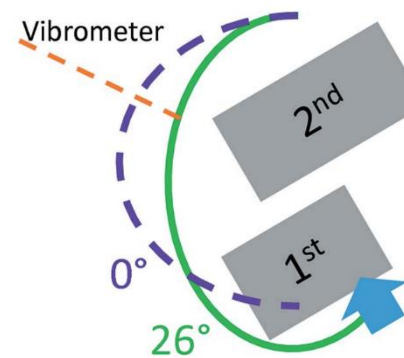
Relative vs absolute vibrations

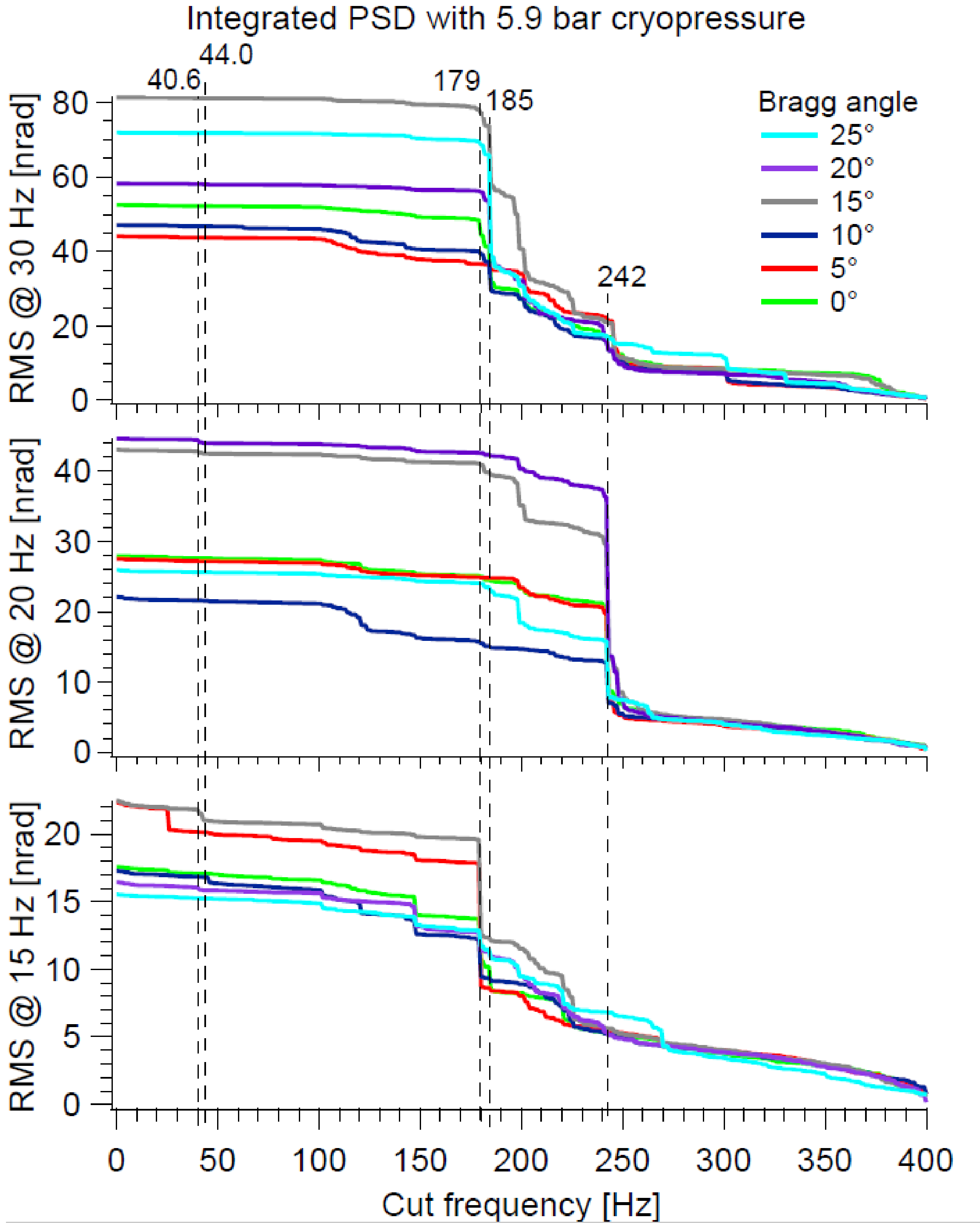


Internal cryo support – absolute vibration




Crystal vs Cryo Support Vibration
Bragg angle
25°
20°
15°
10°
5°
0°
40.6
44.0
78
2
39
35
52
50
40
Solid line = Crystal
Dotted line = Cryo support
RMS vibration [nm]
0
10
20
30
40
Cut frequency [Hz]
0
10
20
30
40
50
60
70
80
to 350 Hz


Vibrometer
2nd
1st
0°
26°



Integrated PSD with 5.9 bar cryopressure
40.6
44.0
179
185
242
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_{pot} = 1500 W
- More rigidity is not always better – frequency band considerations needed
- Lowering the flow rate reduces vibration → higher pressures needed…

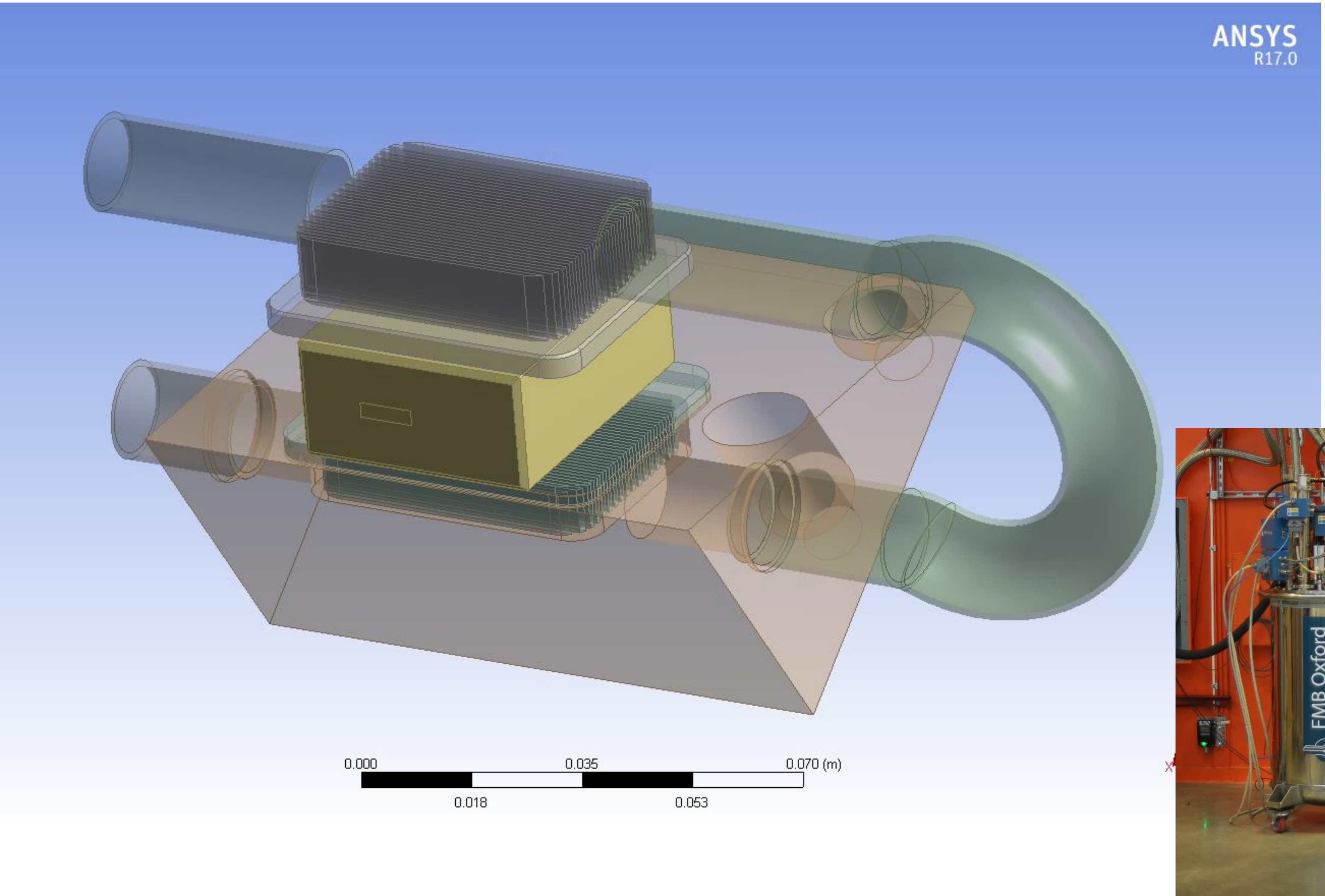
Outlook

- 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 ?

research papers

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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 (LN_2). It is found that it is favorable to circulate the LN_2 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 cryocooling conditions that allow for 1516 W to be adsorbed by the LN_2 before it vaporizes.

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