Studies on Flow-Induced Vibrations for the New High-Dynamics DCM for Sirius

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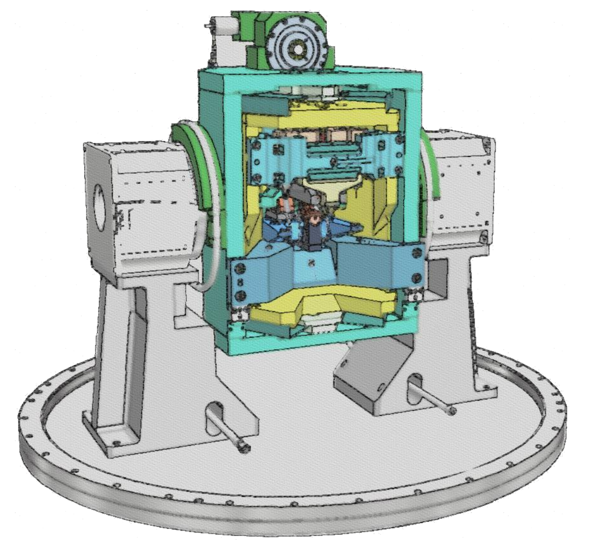
Abstract

The monochromator is known to be one of the most critical optical elements of a synchrotron beamline, since it directly affects the beam quality with respect to energy and position. Naturally, the new 4th generation machines, with emittances in the range of order of 100 pm rad, require even higher stability performances, in spite of the still conflicting factors such as high power loads, power load variation, and vibration sources. A new high-dynamics DCM (Double Crystal Monochromator) is under development at the Brazilian Synchrotron Light Laboratory for the future X-ray undulator and superbend beamlines of Sirius, the new Brazilian 4th generation synchrotron [1, 2]. The disturbances induced by the coolant flows are known to be among the most detrimental influences to a DCM performance, however, quantitative force numbers involved in such disturbances are not commonly investigated. According to the novel dynamic concept, these forces should be predictably translated into stability performance. Therefore, experimental setups that allow the indirect measurement of such forces in conditions close to those of operation were designed. The results comparing different indirect cooling profiles and manufacturing processes (brazing and additive manufacturing) are shown.



Introduction

The goal of this work is to present the flow-induced vibrations experiments, which were designed to provide force frequency spectra of cooling vibrations, so that quantitative data could be available for the project of new high-stability monochromator for Sirius. Details about the full system and its specifications can be found in [2].

DCM Closed loop control

The new high-dynamics monochromator, introduced in the present conference, is a high-end mechatronics system, which is designed to overcome the present stability limitations [3]. Figure 1 depicts a schematic drawing of closed-loop control of the DCM, along with the main disturbance factors:

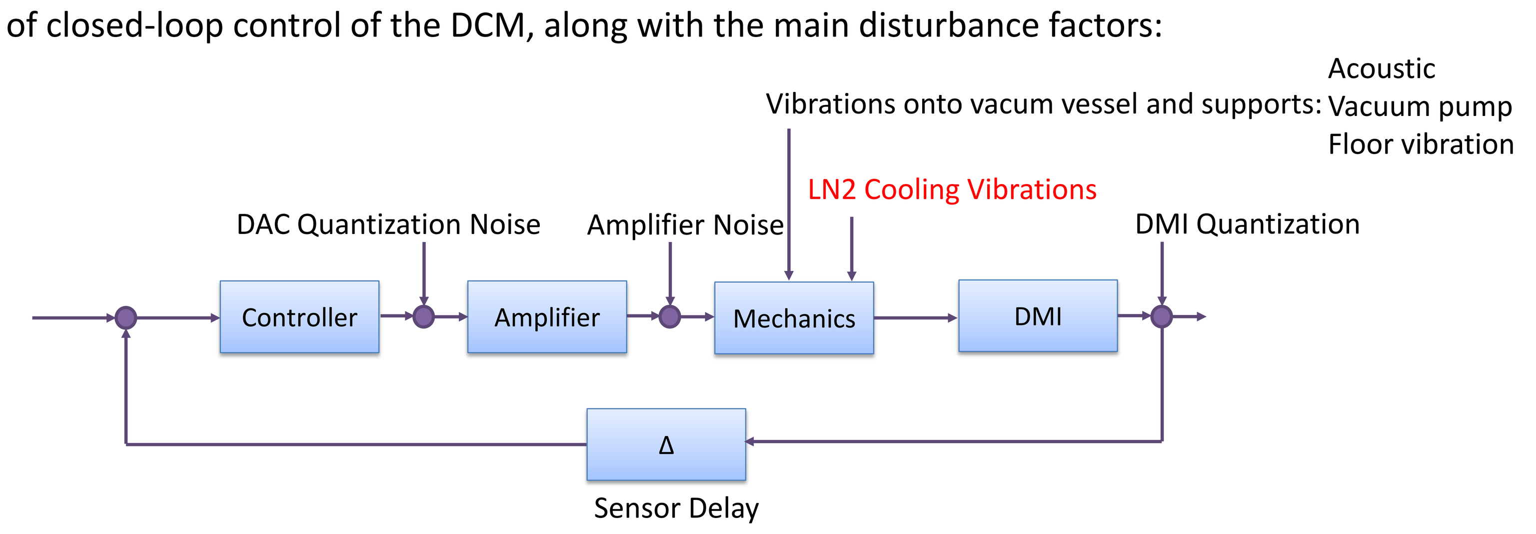


Figure 1: Block diagram of a generic representation of the main disturbances of the closed loop control of the DCM .

Dynamic model

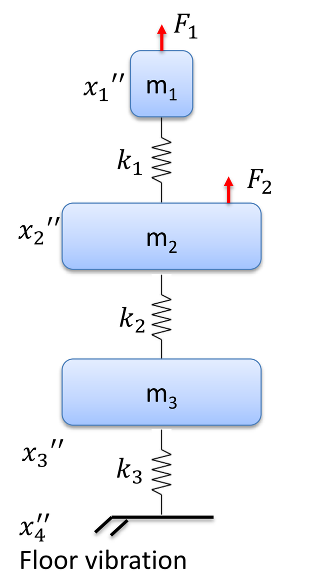
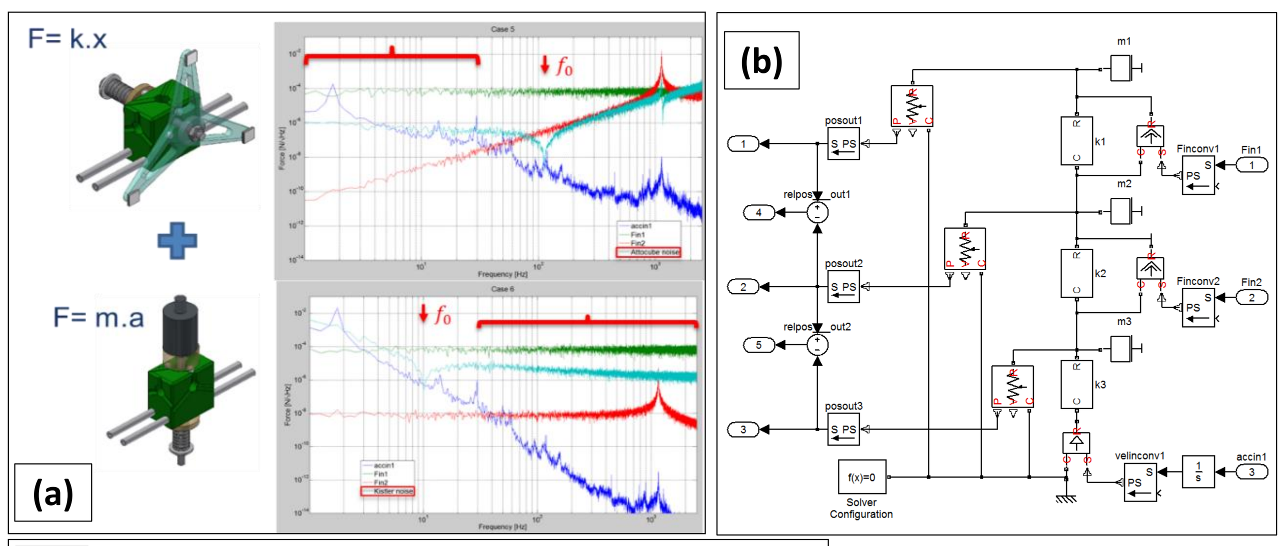


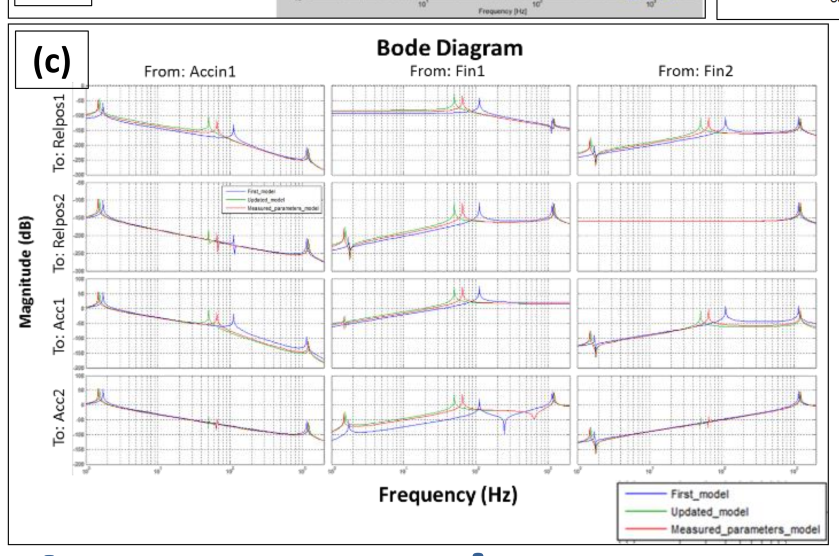
Figure 2: 1D lumped-mass model;

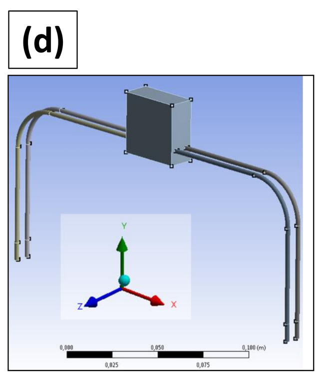
Table 1: Projected masses and stiffness for force high measurement bandwidth

	Case 1	Case 2	Case 3	Case 4
m1 [kg]	0.150	0.180	0.130	0.130
k1 [N/m]	$1.5\cdot10^4$	$1.5\cdot10^4$	$1\cdot10^8$	$1\cdot10^8$
m2 [kg]	2.250	1.850	2.000	2.000
k2 [N/m]	$>1\cdot10^8$	$>1\cdot10^8$	$2\cdot10^5$	800
m3 [kg]	6.000	6.000	6.000	6.000
k3 [N/m]	800	800	800	800
Instrument 1 (main)	Interferometer: m1-m2	Accelerometer: m1	Interferometer: m2-m3	Accelerometer: m2
Instrument 2 (aux.)	Accelerometer: m1	Accelerometer: m2	Accelerometer: m2	Accelerometer: m3
Instrument 3 (aux.)	Accelerometer: m2	-	Accelerometer: m3	-
Description	F1: Low-frequency	F1: High-frequency	F2: Low-frequency	F2: High-frequency

Dynamic concept and simulation







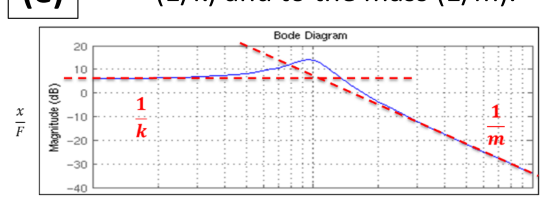
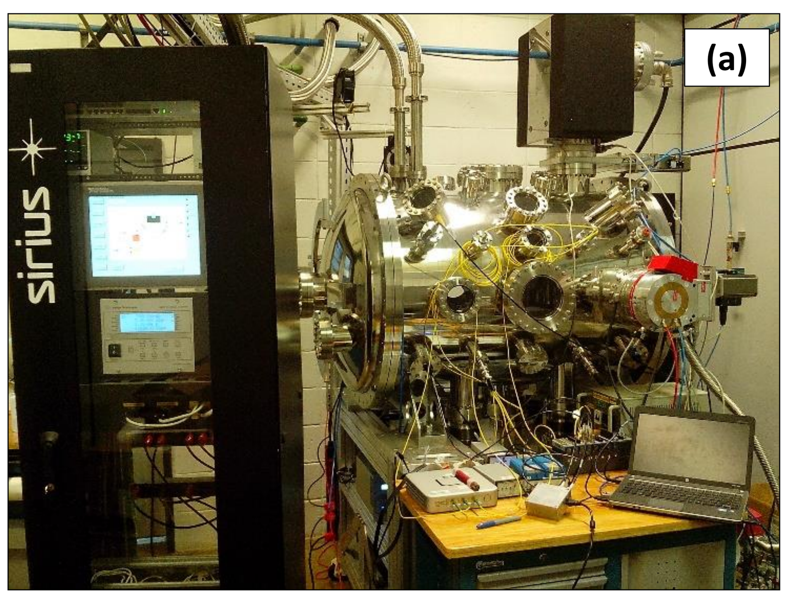


Figure 3: Simulation tools.
(a) Force measurement, using stiffness and position (top) and acceleration and mass (bottom);
(b) Matlab SIMULINK model, used for the dynamic simulation;
(c) MIMO System FRF. Inputs: relative displacement 1 and 2 and accelerations at mass 1 and 2. Outputs: Floor vibration; (acceleration), Force 1 (at the cooling block) and Force 2 (at the manifold).
(d) ANSYS Simulation to determine masses and stiffness;
(e) Bode Diagram for a second order system, showing the frequency range proportional to the stiffness (1/k) and to the mass (1/m).

Instrumentation



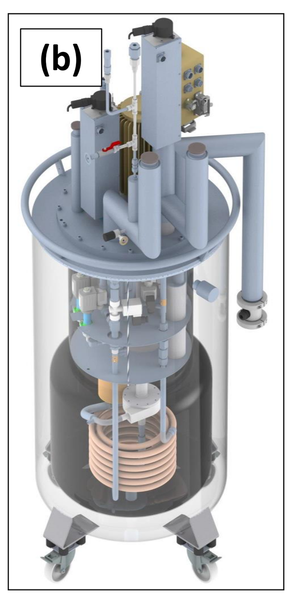
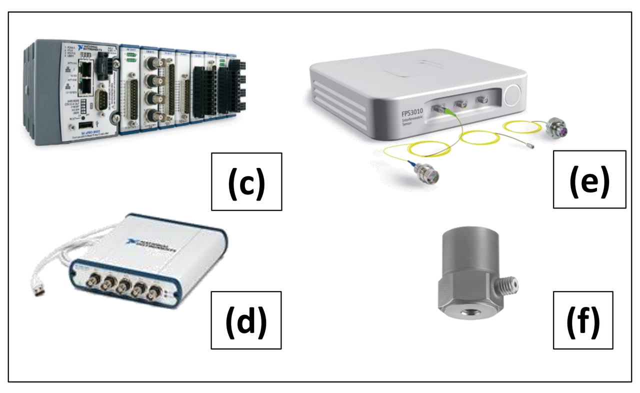
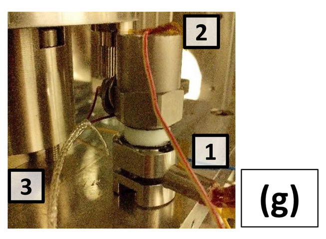


Figure 6 Instruments used in the experiment:
(a) Multi Purpose Vacuum Chamber(in-house development);
(b) FMB Oxford Series F Cryocooler;
(c) National Instruments cRIO-9024 with FPGA and real-time embedded system;
(d) NI USB-4431 24 bit ADC;
(e) AttoCube FPS 3010 Fabry-Perot interferometer;
(f) Kistler 8786A5 accelerometer;
(g) Accelerometer with cartridge heater (1) and thermocouple (2) for local temperature control; Two way cable with external mesh, to reduce noise influence (3);





Design, validation and calibration

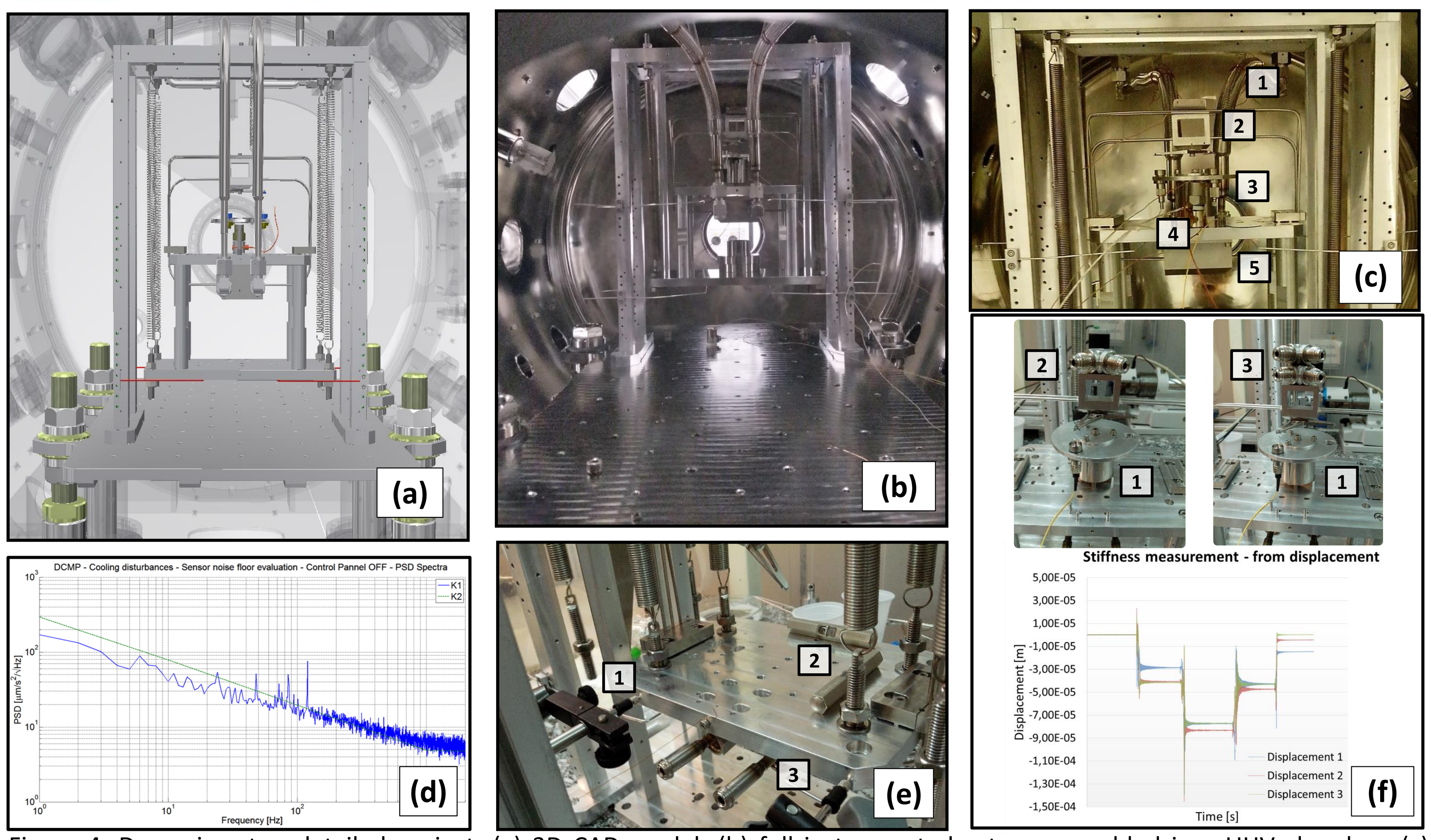
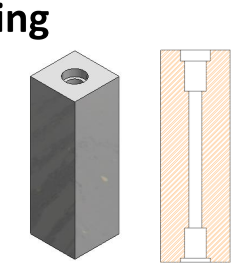


Figure 4: Dynamic setup detailed project: (a) 3D CAD model; (b) full instrumented setup, assembled in a UHV chamber; (c) instrumentation details with LN_2 lines (1), cooling block (2), interferometer (3), accelerometers (4) and manifold (5); (d) Noise floor measurement (with sensor theoretic noise floor and measurement made inside the vacuum chamber); (e) Alignment procedure using bubble level (2) and Heidenhain length gauges (1 and 3) to measure extension springs stiffness; (f) Setup validation through stiffness and masses using the interferometer (1) to measure the displacement (graphic) caused by control mass variation (2 and 3).

Parallel development

Additive manufacturing

Material	Supplier	Leak test result [mbar.l/s]	Approved
CoCr	UNICAMP	1,0e-4	Not OK
SS – PH1	UNICAMP	1,0e-1	Not OK
SS – 316L	Höganäs	1,0e-11	OK



Low-vibration flexible hoses

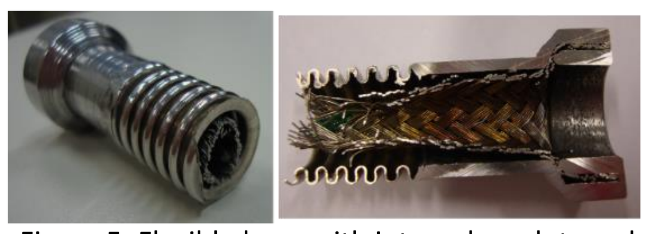


Figure 5: Flexible hose with internal mesh to reduce turbulence and vibration levels in the cooling lines.

Brazing

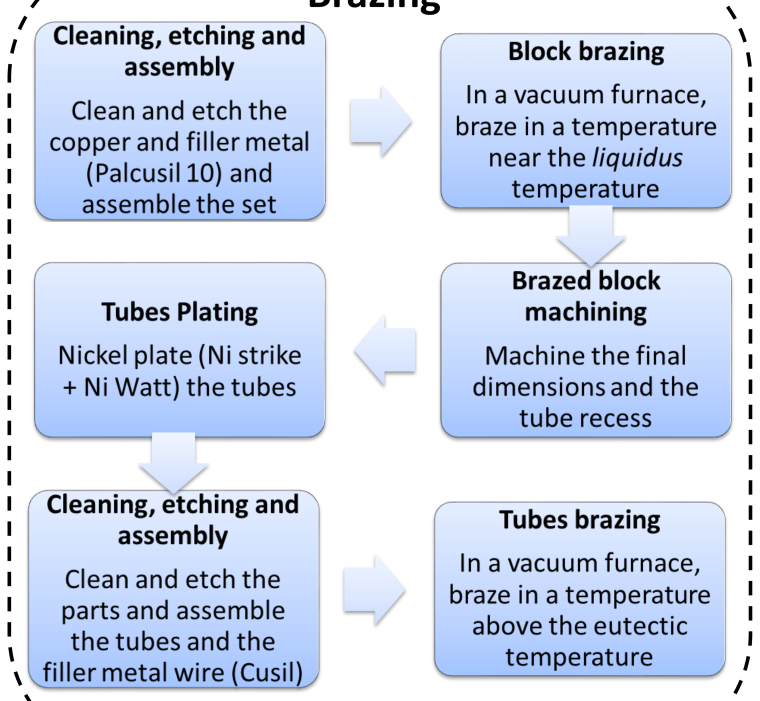
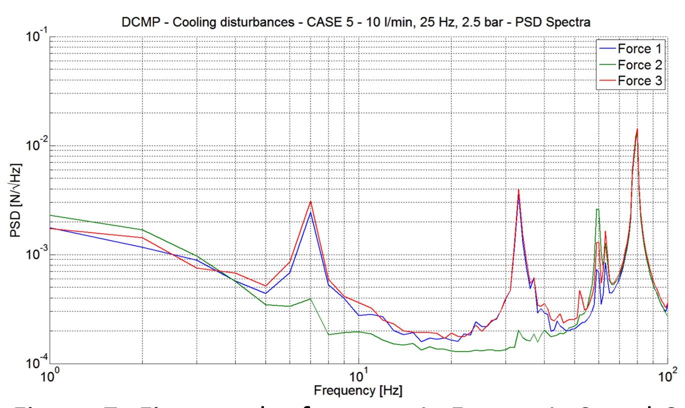


Figure 6: Brazing technology schematic overview

First results



The experiments are still in progress and final results have not been achieved yet. Nonetheless, the method has been validated and the first results are according to the initial force estimates, i.e., in the mN range in the PSD plot, as shown in Fig. 7. Considering Fig. 3(c), the first low-frequency peak, at about 7 Hz, should come from input1-output1 and the last peak, at about 80 Hz, should be the first resonance frequency of input1-output2.

Figure 7: First results for case 1. Forces 1, 2 and 3 come from three simultaneous interferometer readings that measure the displacement of the cooling block. The correlated data provide distance, pith and roll data.

Conclusion

The proposed approach has been successfully validated and conclusive PSD plots of the forces actuating on the first crystal of the high-dynamics DCM for Sirius should be found soon. Different cooling designs are going to be evaluated and the results will guide design targets for the system in the following phases.

Acknowledgement

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