Commissioning and Prospects of the High-Dynamic DCMs at Sirius/LNLS

R. R. Geraldes*, M. A. L. Moraes, S. A. L. Luiz, M. Saveri Silva, R. M. Caliari, A. V. Perna, J. L. Brito Neto, G. S. de Albuquerque, M. A. S. Eleotério
*renan.geraldes@lnls.br, also at the Eindhoven University of Technology (TUe)
LNLS Brazilian Synchrotron Light Laboratory
CNPEM Brazilian Center for Research in Energy and Materials

Abstract

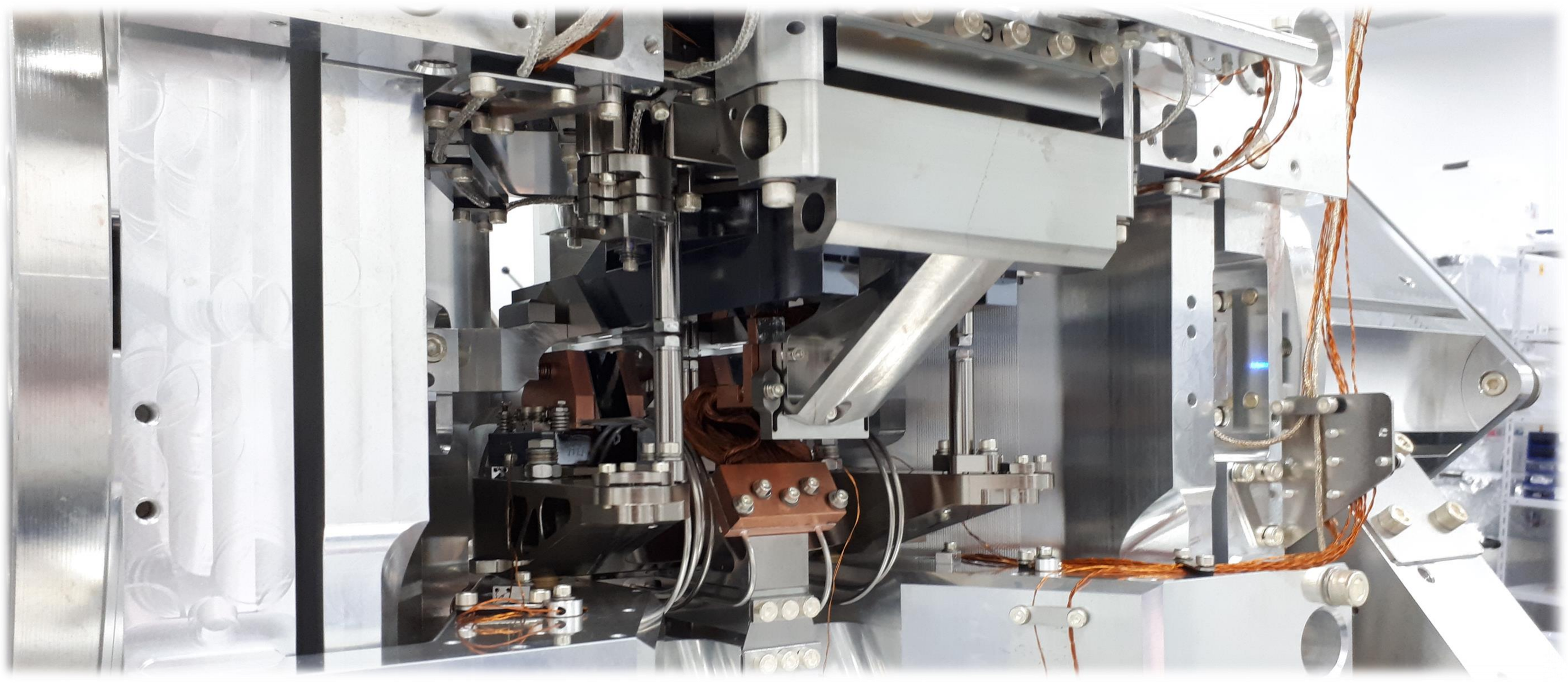
The High-Dynamic Double-Crystal Monochromator (HD-DCM) is an opto-mechatronic system with unique architecture and deep paradigm changes as compared to traditional beamline monochromators. Aiming at unmatching scanning possibilities and positioning stability in vertical-bounce DCMs, it has been developed since 2015 for hard X-ray beamlines of Sirius Light Source at the Brazilian Synchrotron Light Laboratory (LNLS). Two units are currently operational at the MANACÁ (macromolecular crystallography) and EMA (extreme conditions) undulator beamlines, whereas a model for extended scanning capabilities, the so-called HD-DCM-Lite, is in advanced development stage for forthcoming bending magnet and undulator beamlines. This work presents commissioning data related to the two HD-DCM units, together with the developed operation strategies and the overall control architecture, with emphasis on the 10 nrad RMS (1 Hz to 2.5 kHz) pitch parallelism performance, the calibration procedures and flyscan discussions for spectroscopy.

Introduction

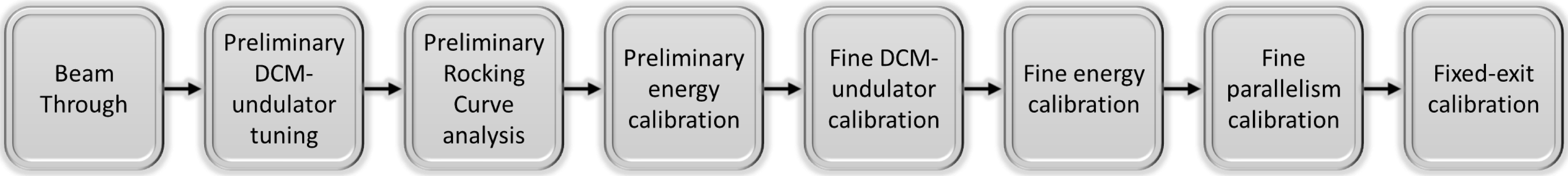
The High-Dynamic Double-Crystal Monochromator (HD-DCM) has been developed by the Brazilian Synchrotron (LNLS) for Sirius and the demanding new generation of X-ray beamlines. Several aspects in the innovative mechatronic design have already been described to the community:

- **MEDSI 2016:** the conceptual design, the mechatronic principles and thermal management solutions [1];
- **ICALEPCS 2017:** in-air validation of the core, system identification, control techniques and prototyping hardware [2,3];
- **MEDSI 2018:** the offline performance of the full in-vacuum cryocooled system, including scans [4];
- **ASPE Topical Meeting 2020:** dynamic modelling work, updated control design and FPGA implementation in the final NI CompactRIO hardware [5-7].

Here, commissioning results of the two operational units at MANACÁ and EMA undulator beamlines at Sirius are presented, together with procedures, strategies, and the related beamline architecture.



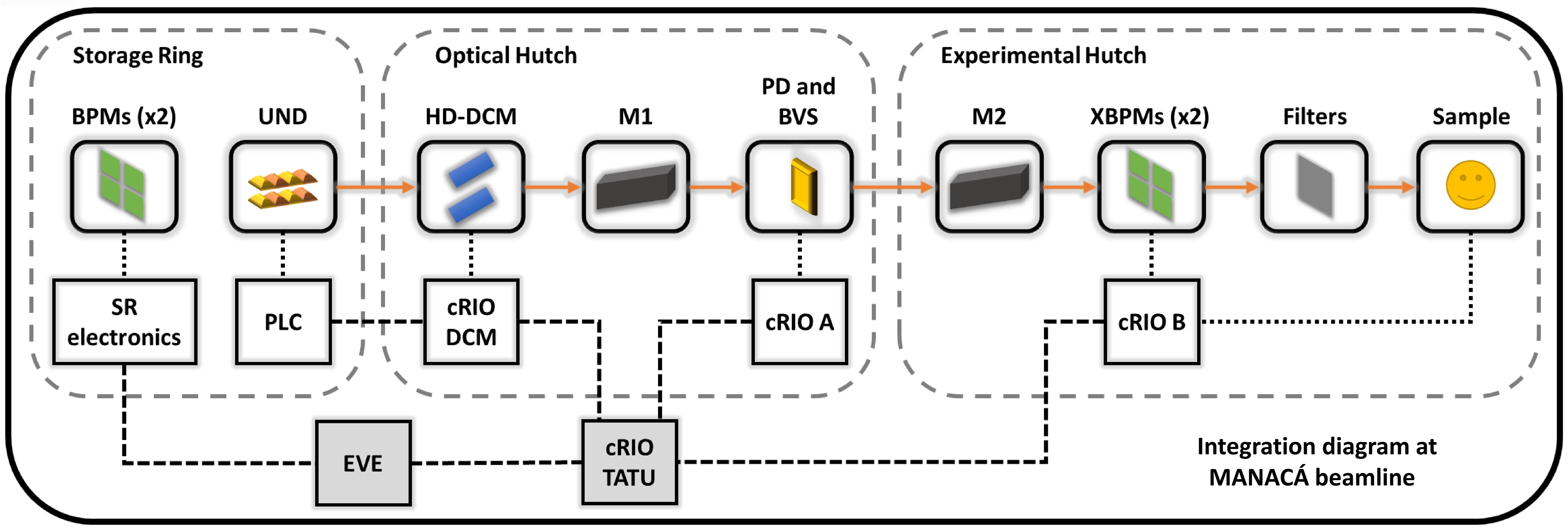
Commissioning Procedure



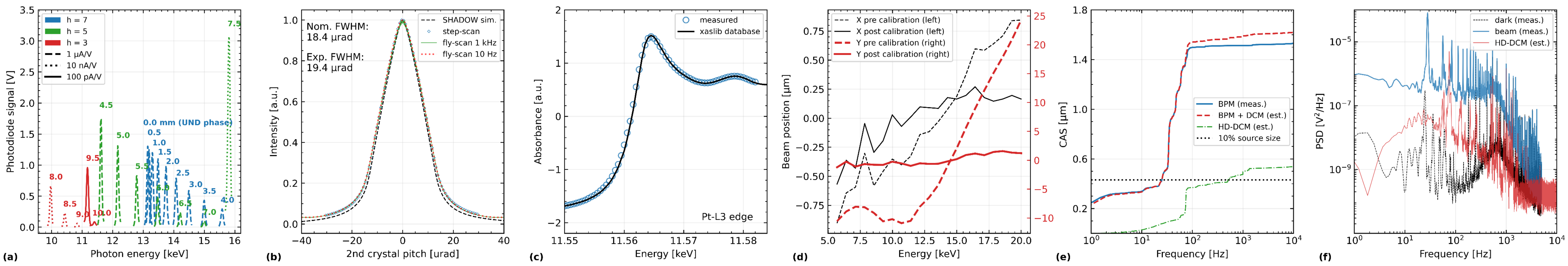
Note: Polynomial-based calibration architecture for flyscan compatibility.

Integration Architecture

- Hardware architecture:
  - Electron beam position monitors (BPMs);
  - Event handler electronics(EVE) (in house dev. GCA group) [8];
  - Undulator (UND);
  - HD-DCM;
  - Photodiodes (PD) and beam visualization systems (BVS);
  - X-ray beam position monitors (XBPMs);
  - Sub-millisecond synchronization;
- Software architecture:
  - Different cascade or triggered control strategies;
  - Acquisition rates at least at 20 kHz (except for the BVS);
  - FPGA-based averaging tool;
  - *Time and trigger unit* (TATU) in cRIO (in house dev. SOL group);
  - Nheengatu solution for EPICS in cRIO (in house dev. SOL group) [9];
  - EPICS-based HD-DCM control library in Python;



Commissioning Results



Commissioning results of the HD-DCM at MANACÁ and EMA beamlines at Sirius: (a) flux-based DCM-undulator tuning; (b) step-scan and flyscan Rocking Curve measurements with Si(111) at 20 keV, taken in 5 minutes and 5 seconds, respectively; (c) absorption edge of Pt at 11.56 keV for energy calibration; (d) X and Y fixed-exit calibration at the sample location via image processing with a CCD-based optical microscope; (e) cumulative amplitude spectrum (CAS) in the vertical axis for the electron beam (without fast orbit feedback correction) and the back-projection of the HD-DCM pitch stability, illustrating its current negligible contribution to the final beam stability; and (f) power spectrum density (PSD) for the attempt of a flux-based pitch stability measurement on the slope of the Rocking Curve for Si(333) at 20 keV, showing a dominant effect in the intensity variation of the source.

Conclusions

This work briefly summarizes the procedures, the integration architecture and some results in commissioning the HD-DCMs that at MANACÁ and EMA beamlines at Sirius. Thus, the innovative mechatronic architecture is now validated, allowing for superior beam position stability and enabling unmatching scanning possibilities, which can be explored for higher throughput or new scientific opportunities. A new model for even faster scans, the so-called HD-DCM-Lite, is now in development.

Acknowledgements

The authors would like to gratefully acknowledge the funding by the Brazilian Ministry of Science, Technology and Innovation; the collaboration with Elina Kasman at APS for the manufacturing of the silicon crystals of both units of the HD-DCM; and the contributions of the LNLS team, the MI-Partners team and of those in the synchrotron community who directly or indirectly built the path to this development. The HD-DCM is also a PhD project carried out with the CST group at TUe, with Marteen Steinbuch and Hans Vermeulen as promotors, and Gert Witvoet as co-promotor.

References

[1] R. Geraldes *et al.*, "The new high dynamics DCM for Sirius", *Proc. MEDSI 2016*, Barcelona, Spain, 2016.
[2] R. Caliari *et al.*, "System identification and control for the Sirius High-Dynamic DCM", *Proc. ICALEPCS 2017*, Barcelona, Spain, 2017.
[3] G. Moreno *et al.*, "Rapid control prototyping tool for the Sirius High-Dynamic DCM", *Proc. ICALEPCS 2017*, Barcelona, Spain, 2017.
[4] R. R. Geraldes, et al. "The status of the new High-Dynamic DCM for Sirius." Proc. MEDSI 2018, Paris, France, 2018.
[5] R. R. Geraldes, et al. "Dynamic error budgeting in the development of the High-Dynamic Double-Crystal Monochromator at Sirius Light Source." Proc. ASPE Topical Meeting 2020, Boston, USA, 2020.
[6] R. M. Caliari *et al.*, "Loop-shaping controller design in the development of the High-Dynamic Double-Crystal Monochromator at Sirius Light Source", Proc. ASPE Topical Meeting 2020, Boston, USA, 2020.
[7] M. A. L. Moraes *et al.*, "The FPGA control implementation of the High-Dynamic Double-Crystal Monochromator at Sirius Light Source", Proc. ASPE Topical Meeting 2020, Boston, USA, 2020.
[8] , J. L. N. Brito, et al. "Status development of sirius timing system." Proc. 15th Int. Conf. on Accelerator and Large Experimental Physics Control Systems (ICALEPCS'15). 2016.
[9] D. A. D. Alnajjar, et at. "PROJECT Nheengatu: EPICS SUPPORT FOR CompactRIO FPGA AND LabVIEW-RT," 17th Biennial International Conference on Accelerator and Large Experimental Physics Control Systems, New York, USA, 2019.

MEDSI CHICAGO 2020

MINISTRY OF SCIENCE, TECHNOLOGY AND INNOVATIONS
PÁTRIA AMADA BRASIL
BRAZILIAN GOVERNMENT