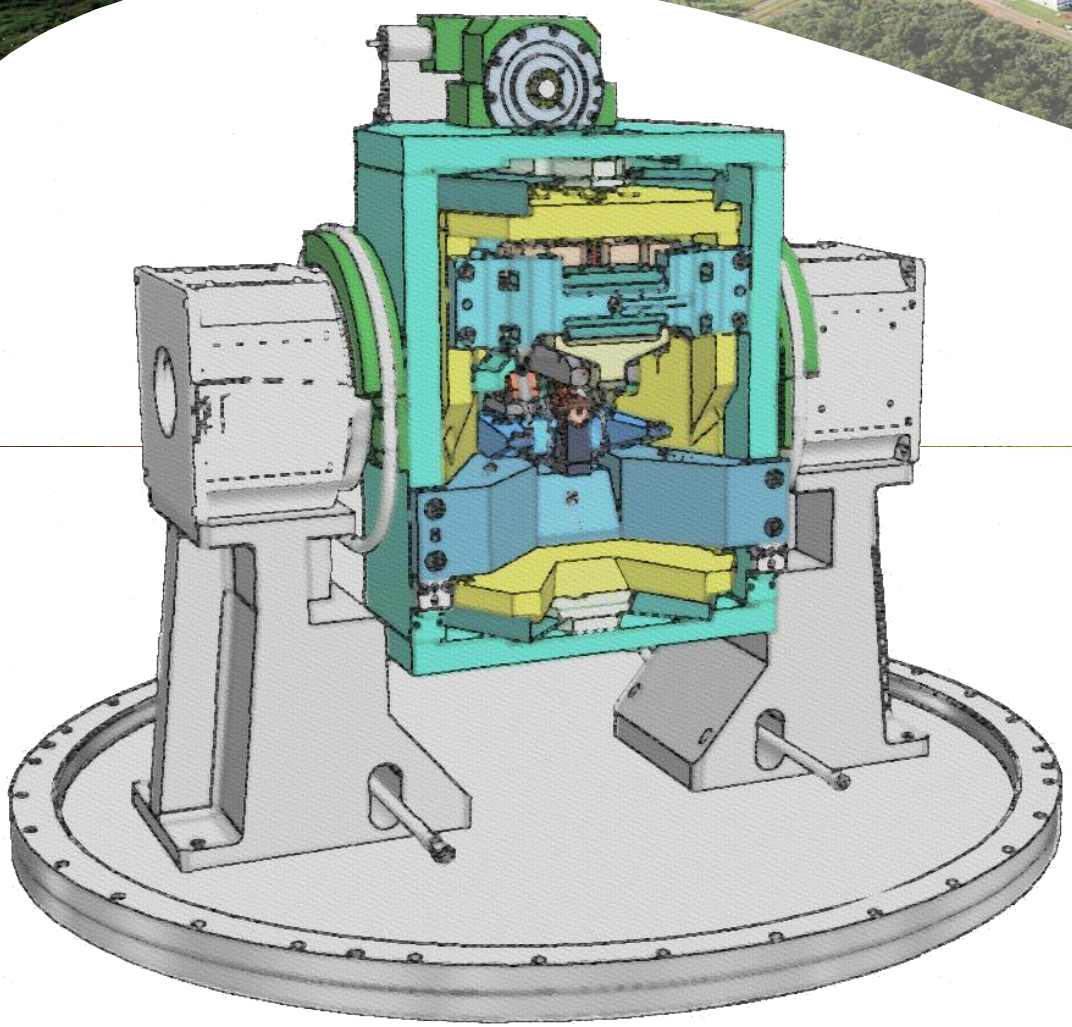
LNLS Laboratório Nacional de Luz Síncrotron — sirius

MI PARTNERS — PARTNERS IN MECHATRONIC INNOVATION

MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES — BRASIL GOVERNO FEDERAL

CNPEM



The New High-Dynamics DCM for Sirius

On behalf of the Beamline Engineering Group of LNLS

September, 13th 2016

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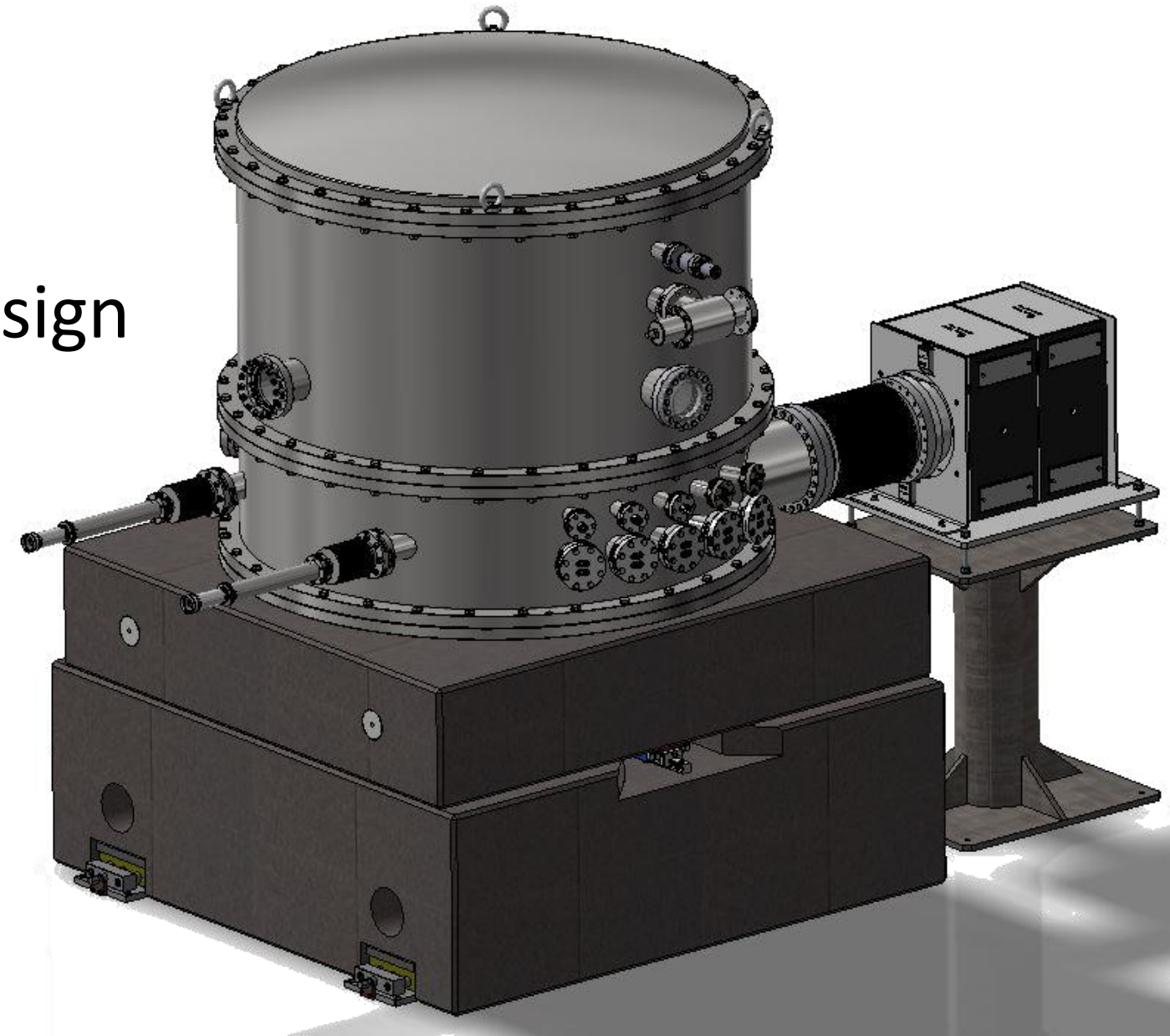
MEDSI 2016
MECHANICAL ENGINEERING DESIGN OF SYNCHROTRON RADIATION EQUIPMENT AND INSTRUMENTATION

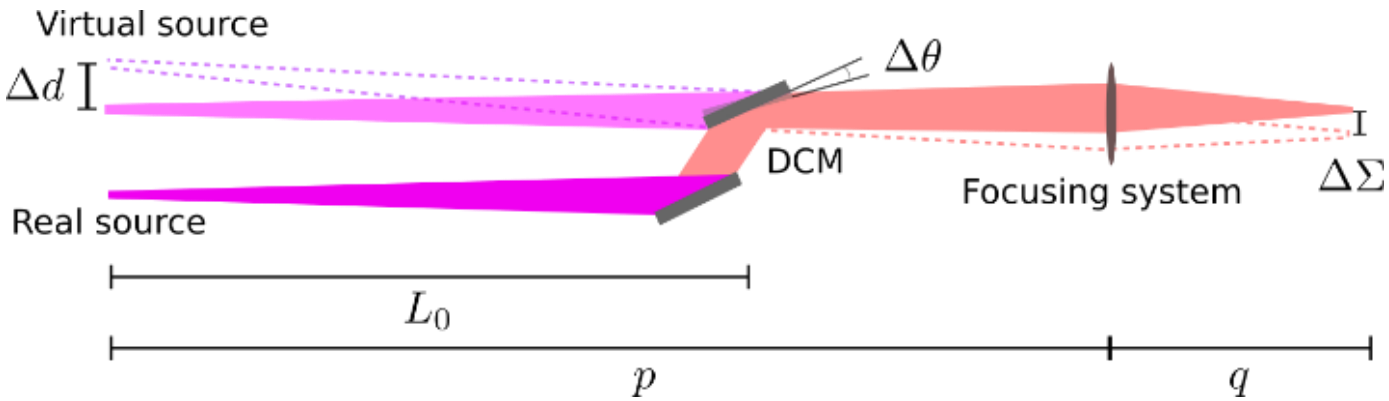
Summary

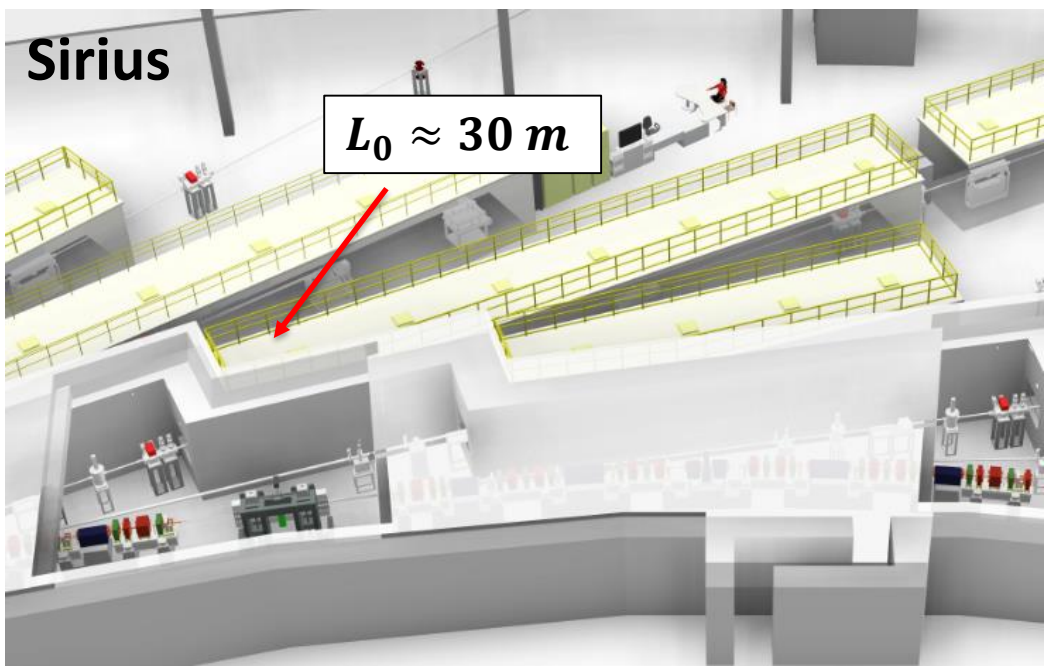
- Motivation
- Specifications
- Concepts
- Mechanical Design
- Conclusions



Motivation

DCM performances for the next generation machines





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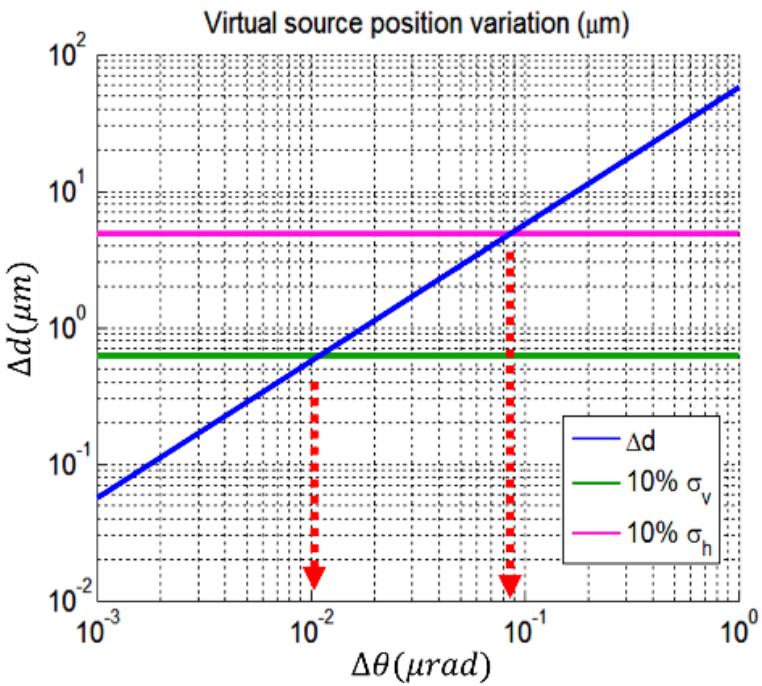


Specifications

Parameter	Description
Type:	Vertical DCM
Beam offset:	18 mm
Angular range:	3 to 60°
Angular resolution:	0.2 µrad
Pitch/roll stability:	in-position: **< 10 nrad** ($\pm 3\sigma$) flyscan: 200 nrad ($\pm 3\sigma$)
Crystal sets:	Si(111): 2.3 to 38 keV Si(311): 4.4 to 72 keV
Crystal sizes (W x L):	1st crystal: 15 x 35 mm^2 2nd crystal: 15 x 190 mm^2
Crystal cooling:	1st crystal: Indirect LN_2 (80 K) 2nd crystal: Copper straps (155 K)
Crystal DoF:	1st crystal: fixed at rotation center 2nd crystal: gap, pitch, roll
Beam size:	1.7 x 1.7 mm^2
Input Power:	150 W
Base pressure:	< 5 x 10^{-8} mbar

Design Guidelines

Degrees of freedom

- **Problem:**
  complexity and instability
- **Solution:**
  Bragg, gap, pitch, roll

Closed-loop control bandwidth

- **Problem:**
  limited control bandwidth
- **Solution:**
  low-stiffness actuators with reaction mass

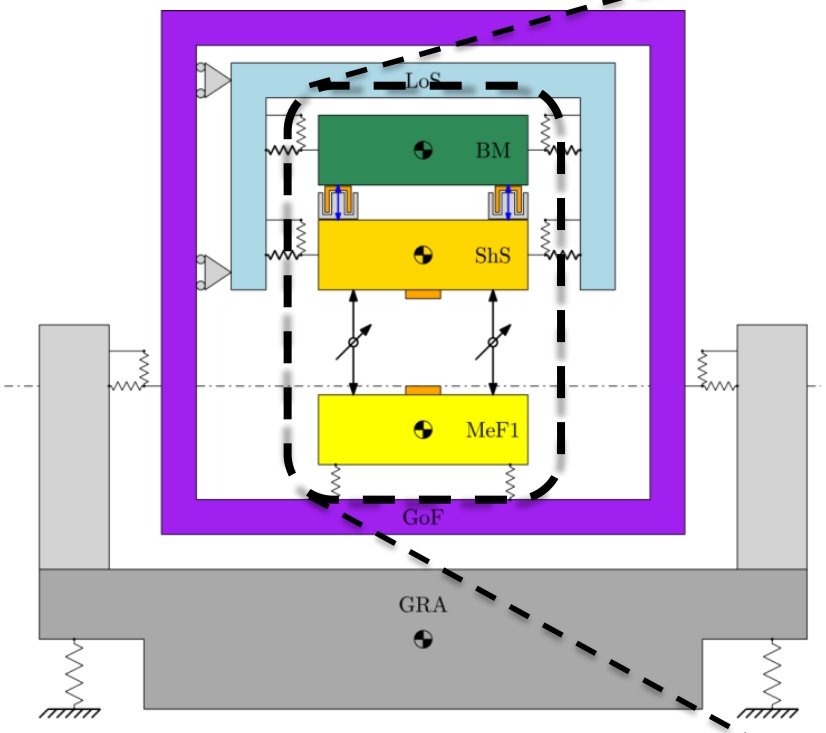
Cooling disturbances

- **Problem:**
  flow vibrations
- **Solution:**
  taylored and balanced cooling channels

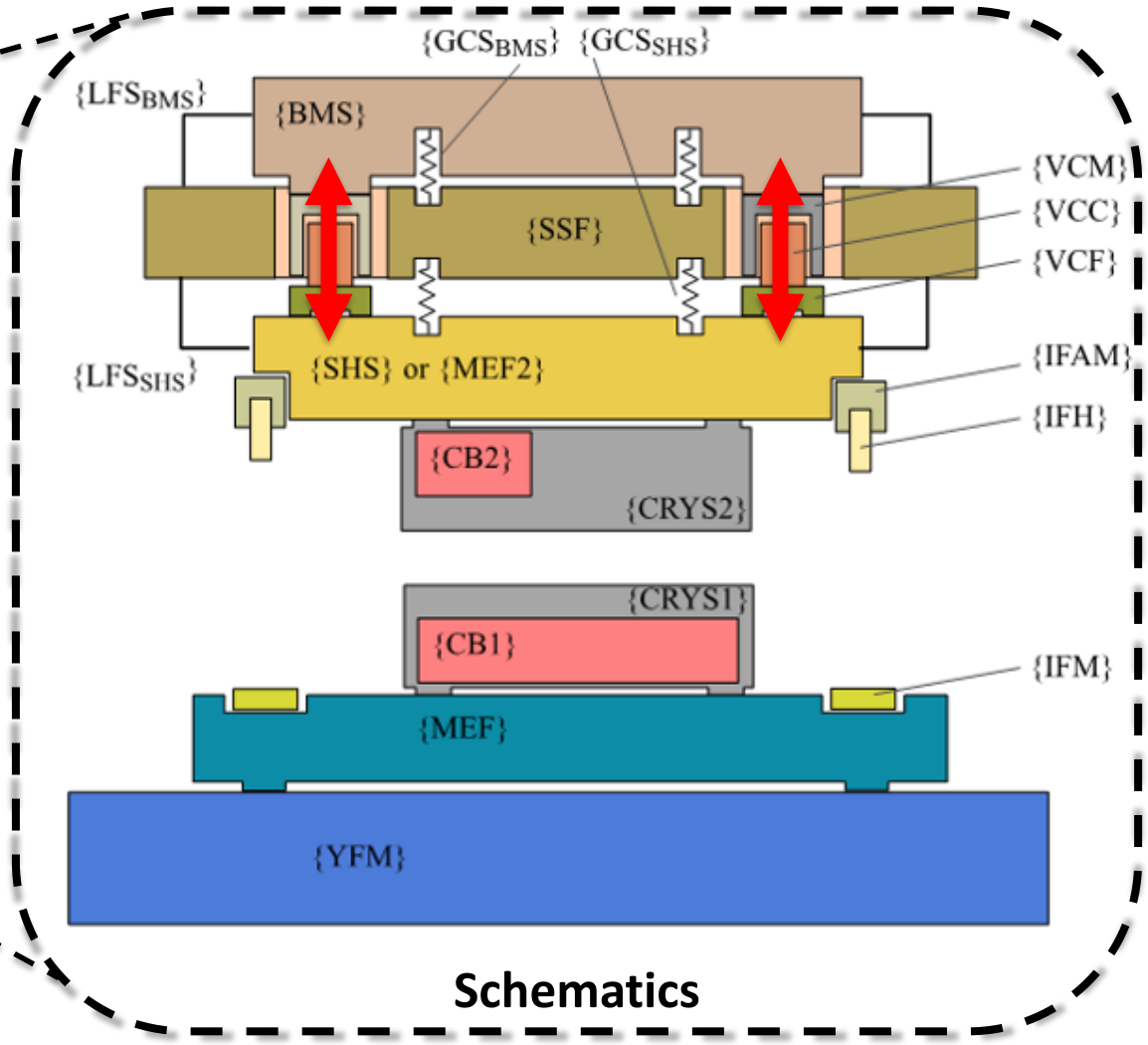
Feedback

- **Problem:**
  sampling rate/precision/availability
- **Solution:**
  internal metrology

Concept

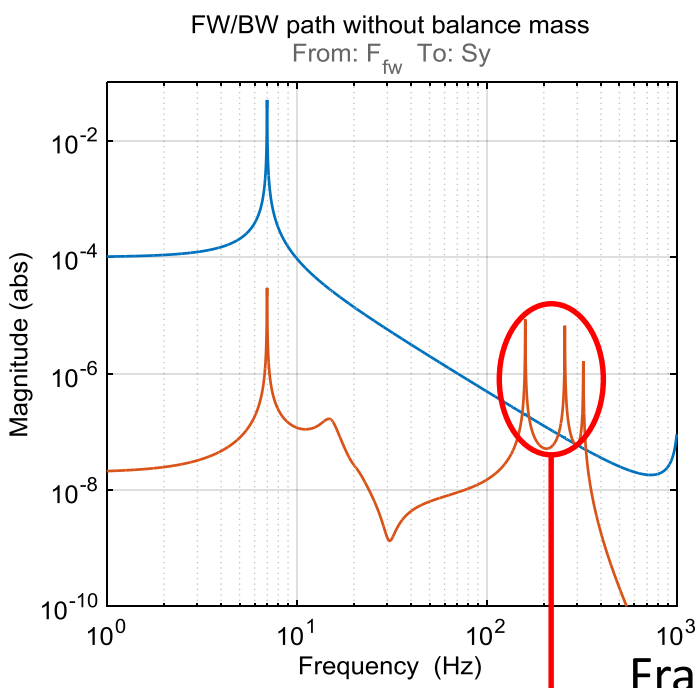


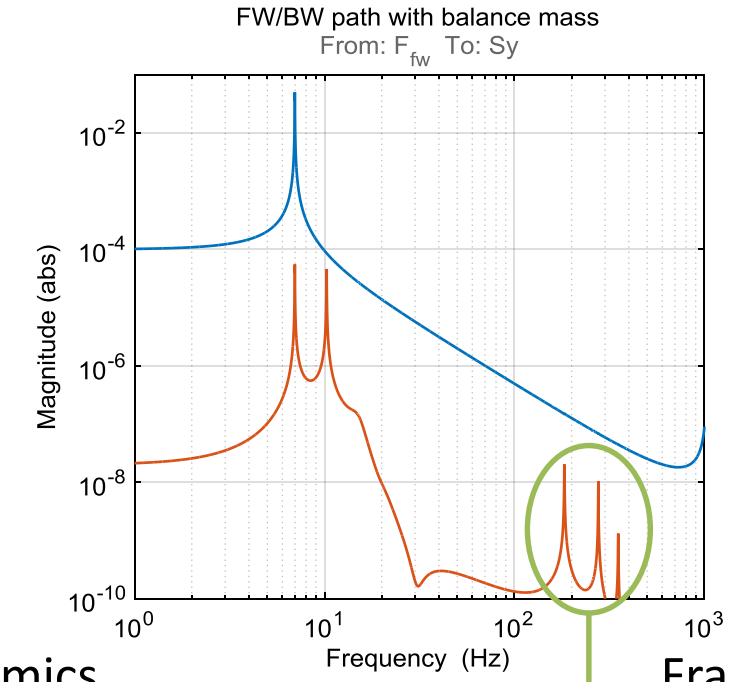
1D dynamic model



Schematics

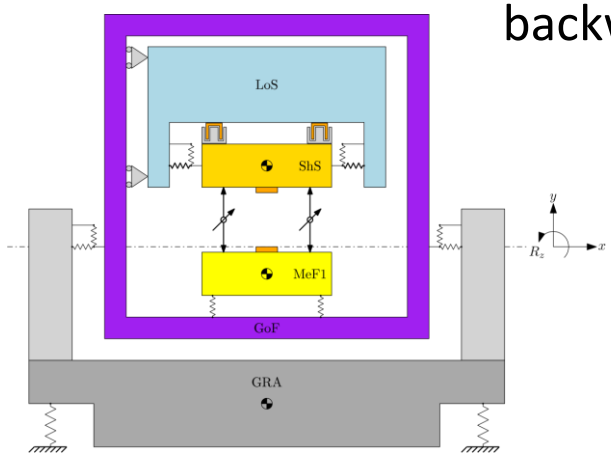
Reaction Mass

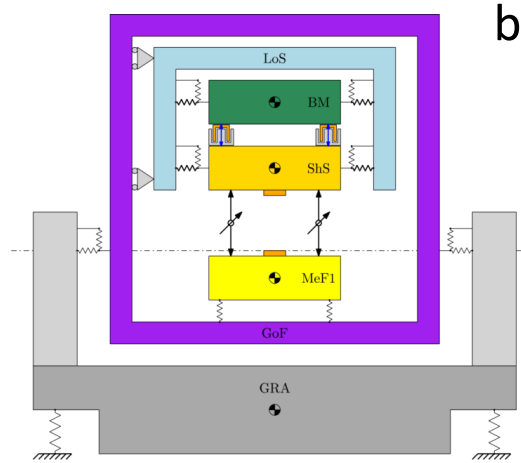




Frame dynamics excited in backward-path.

Frame dynamics excitation reduced by balance mass.

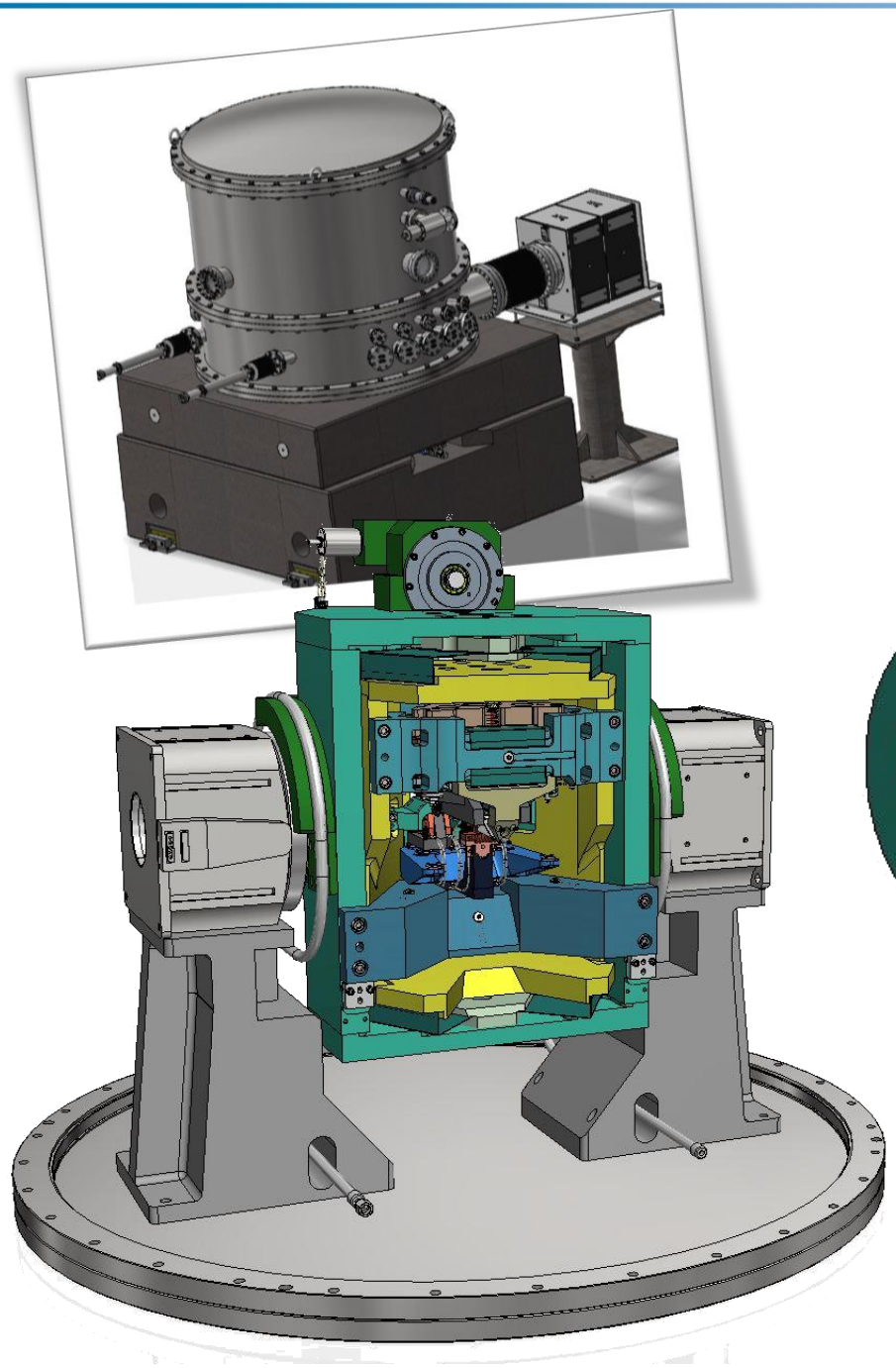


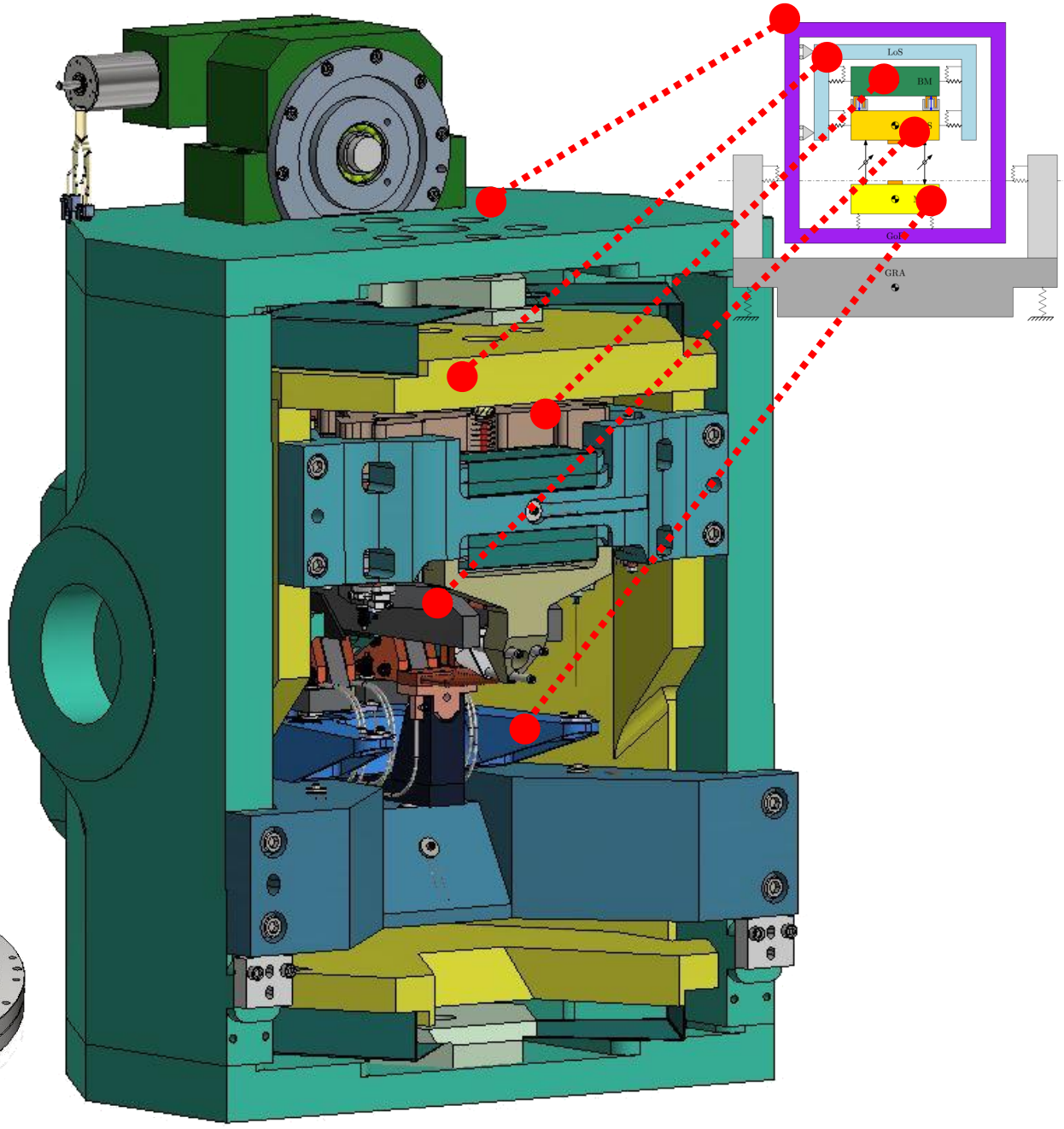


Actuators

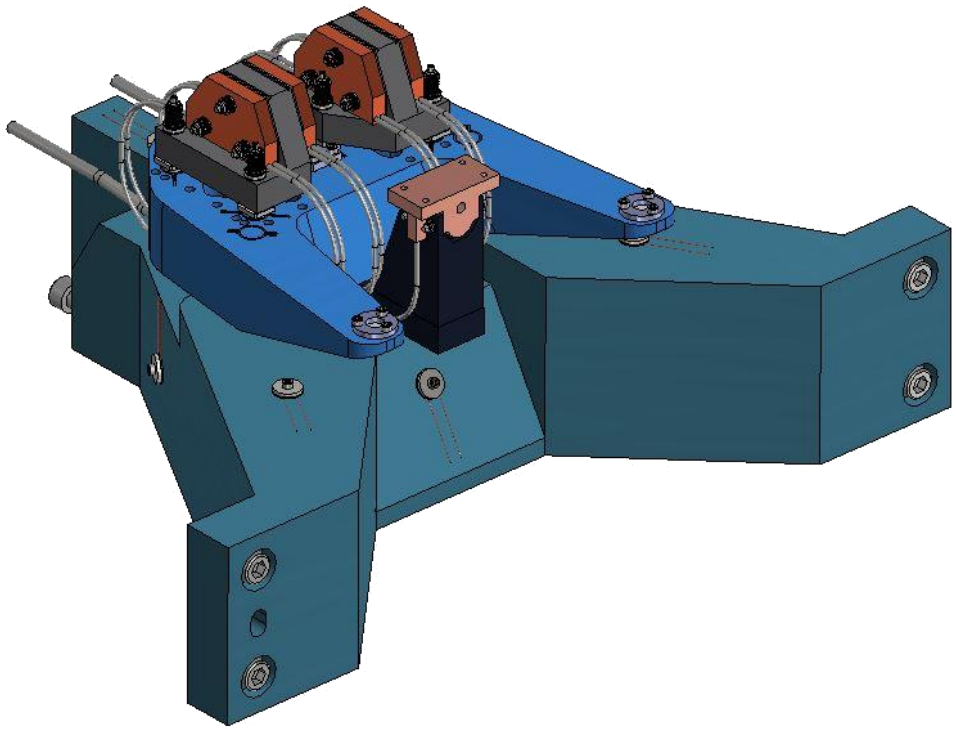
	Lorenz (VC) [nrad] (3σ)	**Piezo Stack** [nrad] (3σ)	**Piezo Walker** [nrad] (3σ)
Floor vibrations	0.8	2.5	0.9
LN_2 vibrations	?	?	?
Amplifier noise	1.4	44.1	2.9
Amplifier DAC quantization	0.2	0.2	0.2
DMI quantization errors	0.2	0.1	0.1
Quadratic sum	**1.6**	**44.1**	**3.1**
Bandwidth (Hz)	**200**	**20**	**20**
Flyscan Compatibility	✓	✗	✗

Mechanical Design



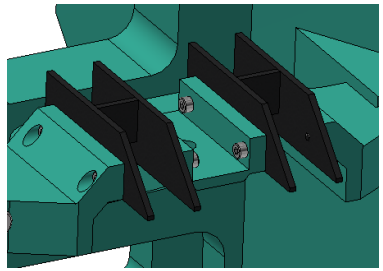


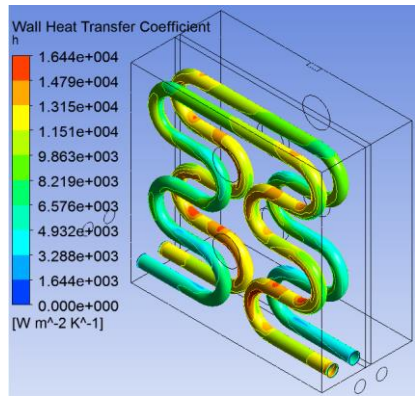
Highlights



Disturbances

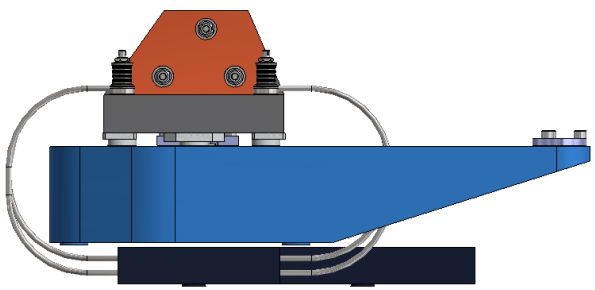
- Cooling solutions for vibration reduction (and **measurements!**)
- Shielding “away” from crystals (GOF)

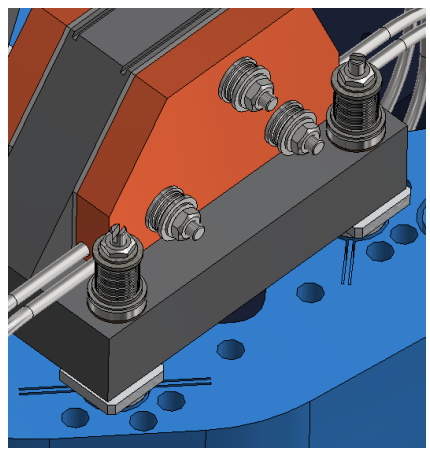




Metrology

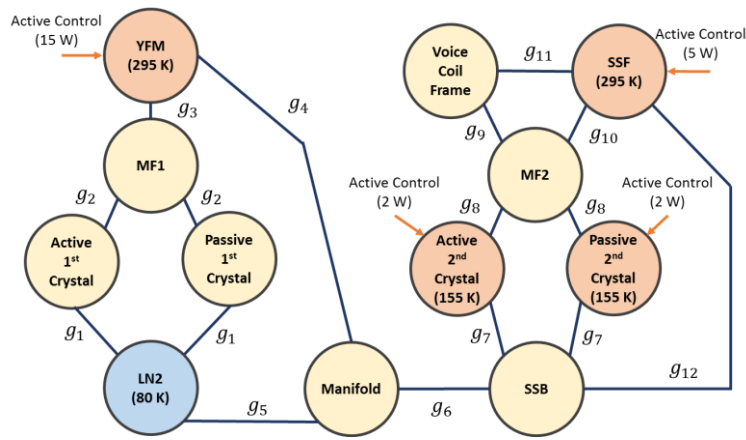
- Embedded metrology with nanometric performance
- Deterministic clamping for crystals
- Compliant cooling structures





Thermal management

- Active thermal control



Conclusions

- All is running according to plan and a functioning prototype should be ready in mid-2017;
- The high-dynamics concepts are proven technology in the semiconducting industry and are now applied to this DCM.
- With 200 to 300 Hz servo bandwidth estimate, the stability target has been confidently pursued;
- Extensive mechanical, thermal, alignment and control analyses have been made in a predictive modelling approach.
- Concerning motion control and metrology for beamline instrumentation, this project has headed an unprecedented boost in competences and infrastructure at LNLS;
- These new engineering concepts have already started to be applied to projects of other opto-mechanical devices;
- Patent pending (INPI BR 10 2016 020900 5).

(Note: Dedicated posters about the mechatronics concept, flow-induced vibrations, thermal management and clamping complement this oral presentation.)

Acknowledgements

The authors would like to gratefully thank:

- Brazilian Ministry of Science, Technology, Innovation and Communication;
- LNLS team;
- MI-Partners team;
- The community;
- The organizers;
- The audience.

Appendix: Specifications

General

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Control

	GOF	LOS	SHS	Therm.
Actuator Type:	Torque Motor	Servo	Voice-Coils	Foil Heaters
Sensor Type:	Rotary Encoder	Linear Encoder	FP IFM's	NTC RTD's
Resolution:	<50 nrad	<0.1 µm	< 0.5 nm/ 5 nrad	<10 mK
Closed-Loop BW:	35 Hz	20 Hz	200 to 300 Hz	0.1 Hz
Feedback Sampling:	10 kHz	10 kHz	10 kHz	20 Hz