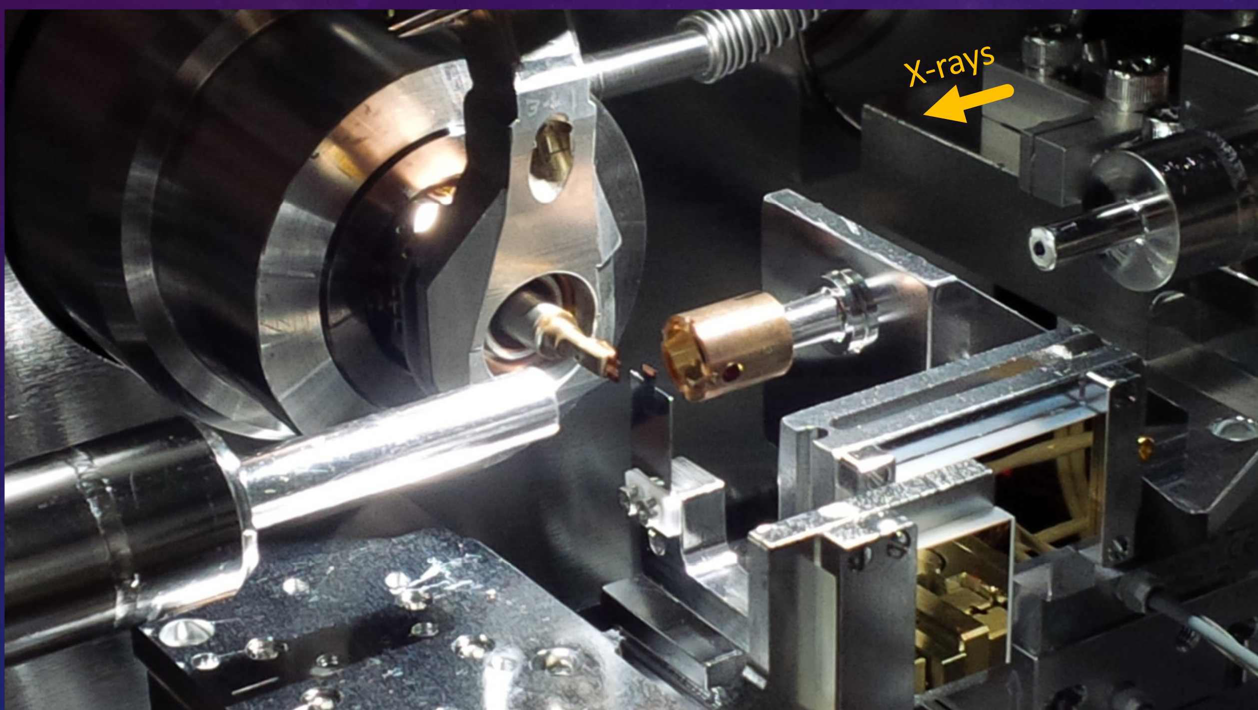
Mechanical Engineering of a Cryo-STXM at CLS

C. N. Regier, Adam F.G. Leontowich, D.M. Taylor

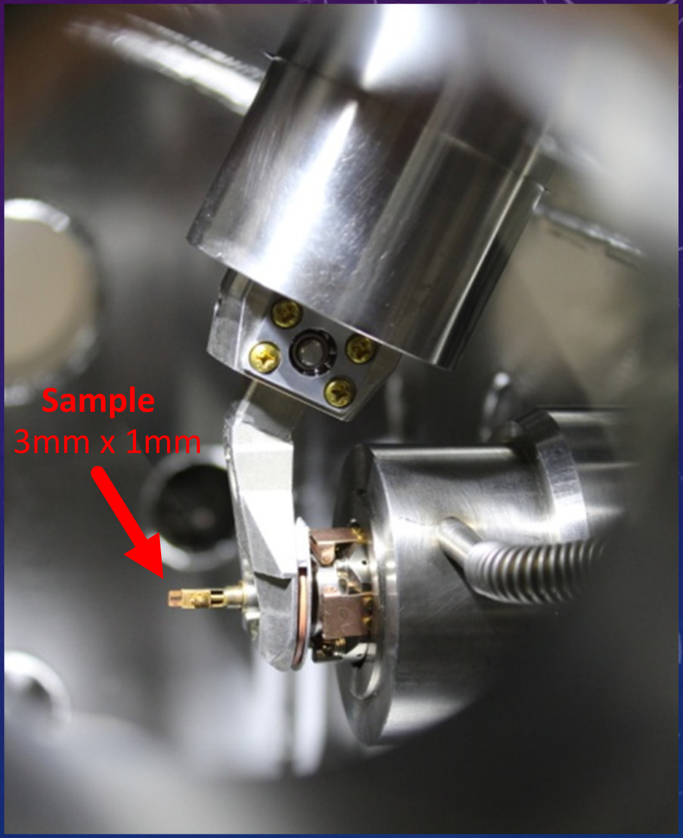


Canadian Light Source
Centre canadien de rayonnement synchrotron

XRM2018
INTERNATIONAL CONFERENCE
X-RAY MICROSCOPY

Outline

- The Canadian Light Source
- The SM Beamline at CLS
- STXM Basics
- Cryo-STXM Parameters
- Goniometer
- Design Problems and Solutions
- Final Result
- Acknowledgements



The Canadian Light Source

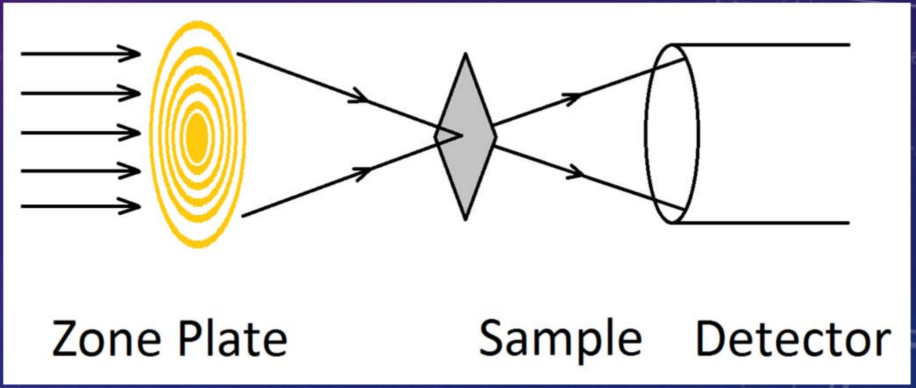
- CLS is a third-generation synchrotron
  - Located in Saskatoon, Canada
    - Prairie city
    - Population ~ 250,000
    - Very cold in winter (-10 to -40 C!)
    - Very nice in summer (+20 to +35 C)
- 16 operating beamlines
- Ring circumference: 171m

The SM Beamline at CLS

- ID Beamline
  - Apple II EPU
- Plane-grating monochromator
  - 130-2500 eV range
- Three end-stations on two branches
  - XPEEM
  - STXM
  - Cryo-STXM

STXM Basics

- STXM = Scanning Transmission X-Ray Microscope
  - Similar to STEM, but uses x-rays
- 3 main elements
  - Zone plate
  - Sample
  - Detector
  - Also can use OSA
- STXM at CLS
  - 30 nm beam spot size
    - Limited by zone plate etching



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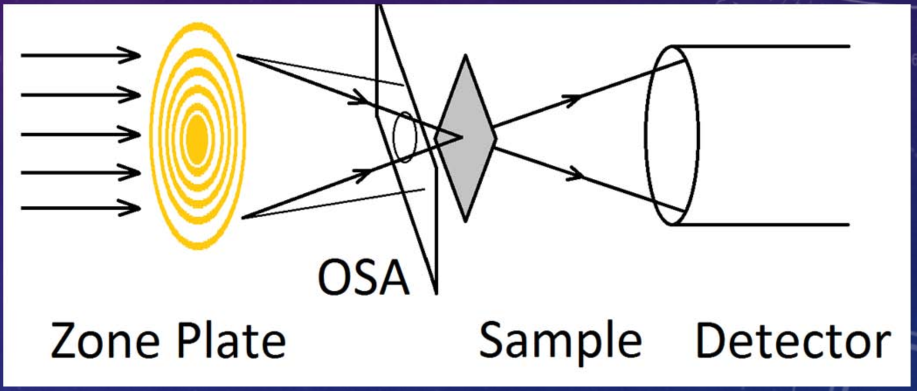


Cryo-STXM Parameters

- STXM with sub 30 nm resolution
- Sample cooling to near liquid nitrogen temperatures
- Ability to introduce cold sample through a load-lock
- Sample tomography (rotation) to +/- 70 deg or more
- Near- or Full-UHV
    - Prevents ice formation on sample
- Can also function as conventional STXM
    - At atmospheric pressure or in vacuum
- Zone plate sample scanning

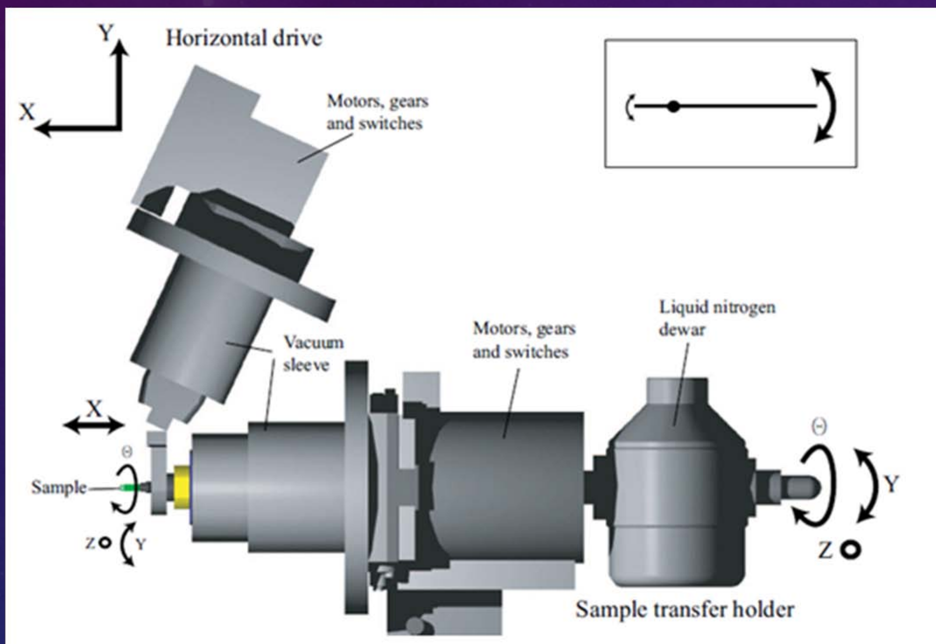
Cryo-STXM Parameters

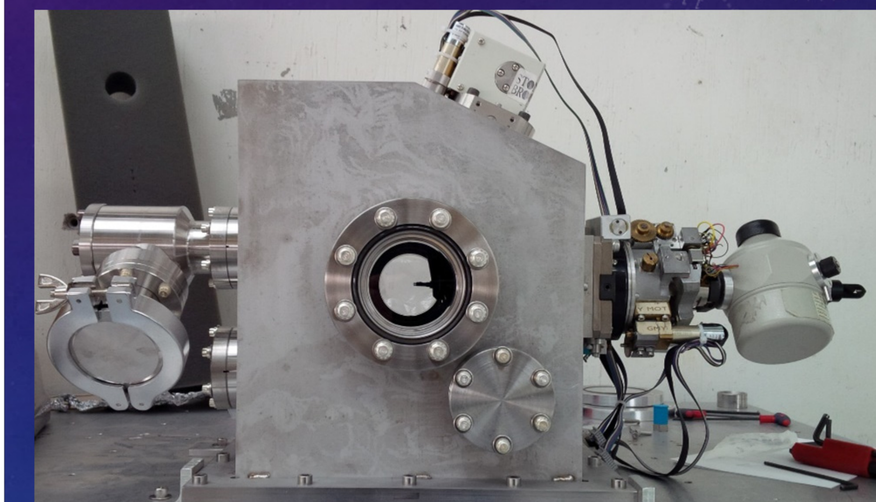
Vacuum Level	≤10^{-8} Torr
Sample Temperature	≤ -175 C (98 K)
Vibration at Sample	≤ 5 nm RMS from 0 to 200 Hz
Zone Plate Scanning Resolution (X,Y)	≤ 1 nm
Conventional Sample Scanning Resolution (X,Y)	≤ 5 nm
Detector Stage Resolution (X,Y)	≤ 50 µm
Sample Rotation	≥ +/- 70 deg

- Only soft x-ray STXM in the world capable of cryo-tomography

Goniometer

- ➢Electron microscopy has a solution:
  - ➢JEOL cryo-tomography goniometer

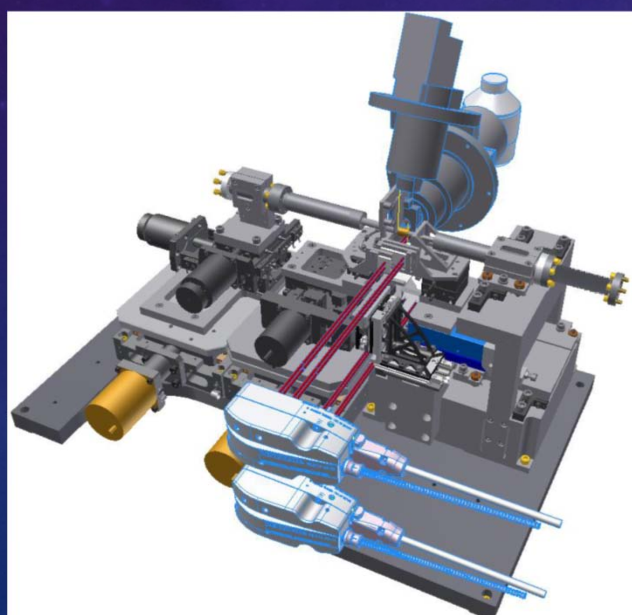


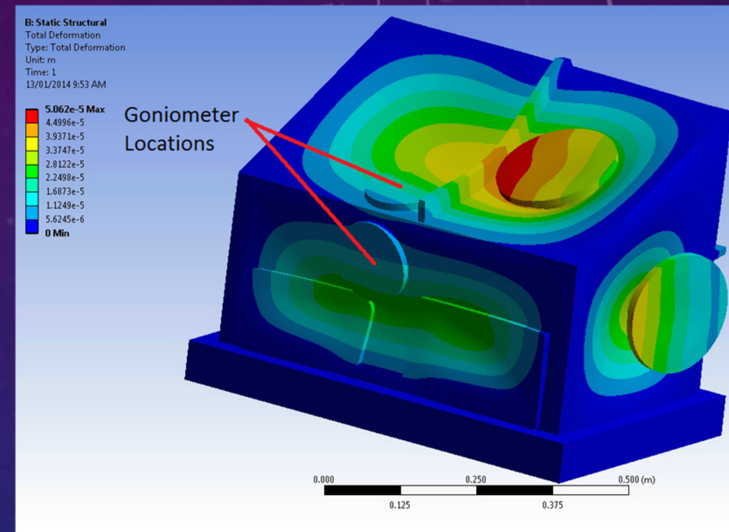


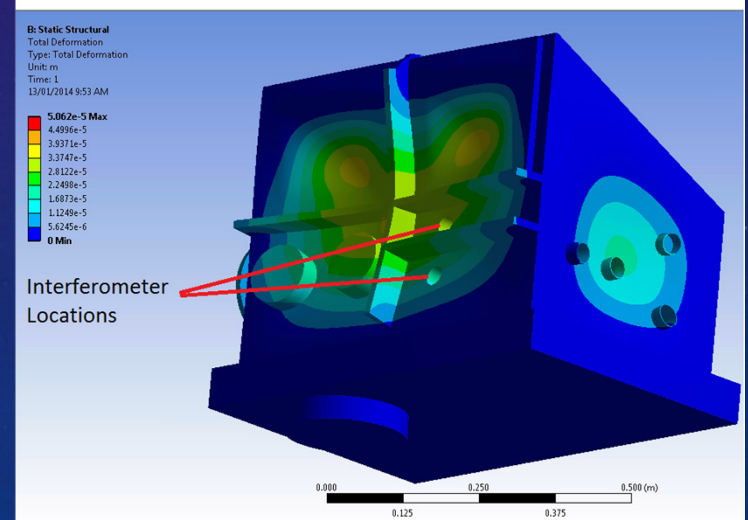
From: T. Beetz, “Soft X-Ray Diffraction Imaging With and Without Lenses and Radiation Damage Studies,” Ph.D. Thesis, Physics Dept., Stony Brook University, Stony Brook, NY, 2004.

Design Problems and Solutions

- Positioning:
  - Renishaw RLE20 laser interferometer
    - Sub nm measurement
  - Heads mounted outside vacuum
    - Tank wall can't flex too much – loss of signal

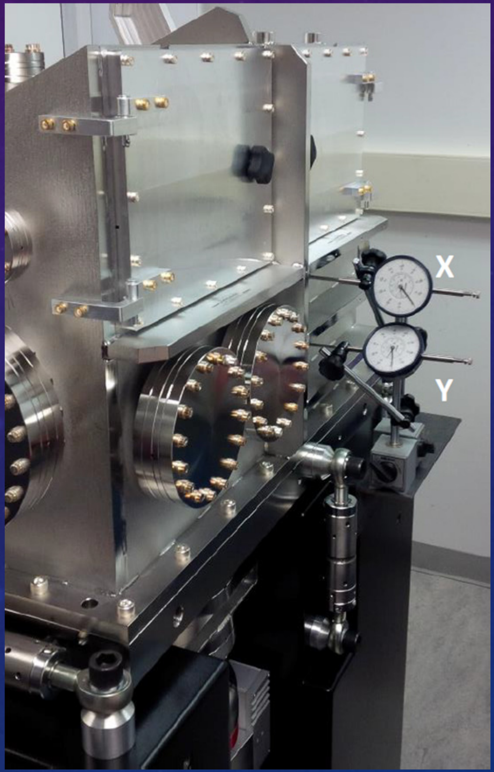


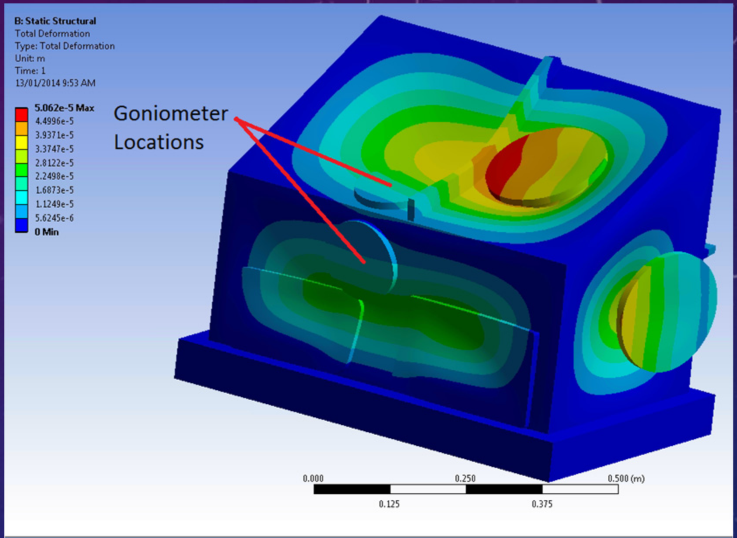


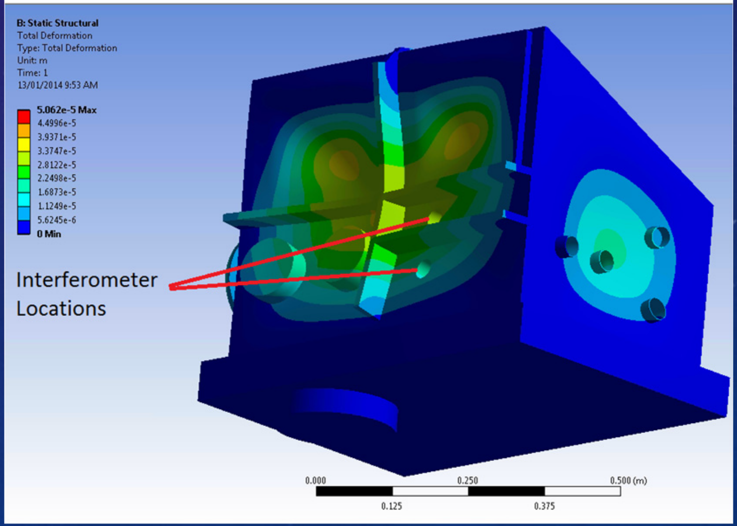


Design Problems and Solutions

- Positioning:
  - ANSYS predicted
    - X = 28 µm
    - Y = 15 µm
  - Actual
    - X = 29 µm
    - Y = 25 µm

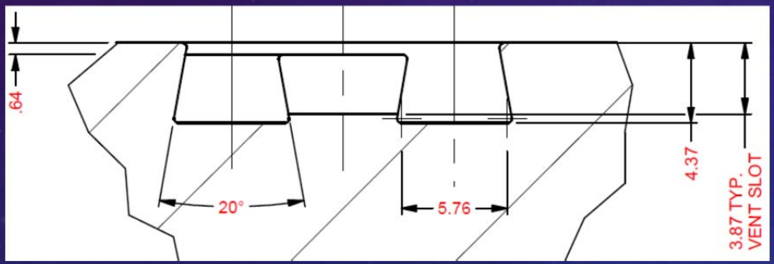


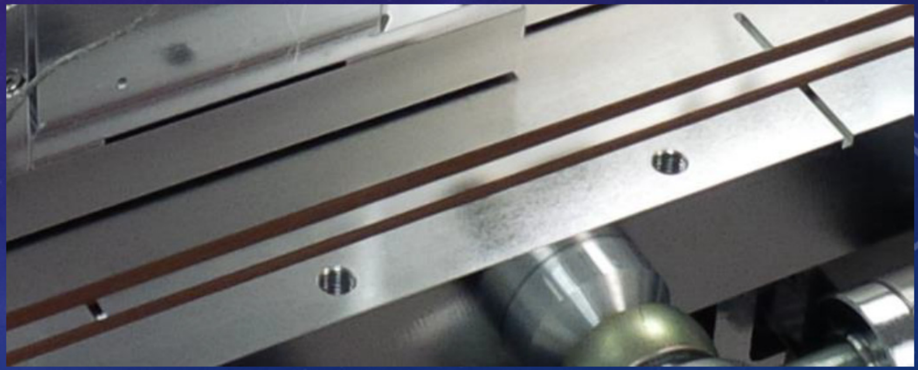




Design Problems and Solutions

- Vacuum:
  - Conflats where possible
    - Can’t open often
    - Limited size/shape
  - O-rings for other seals
    - Double O-ring with differential pumping





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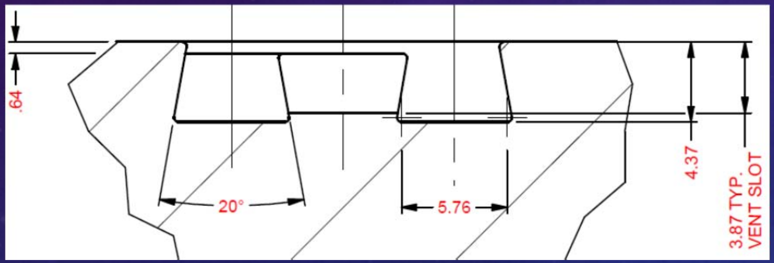

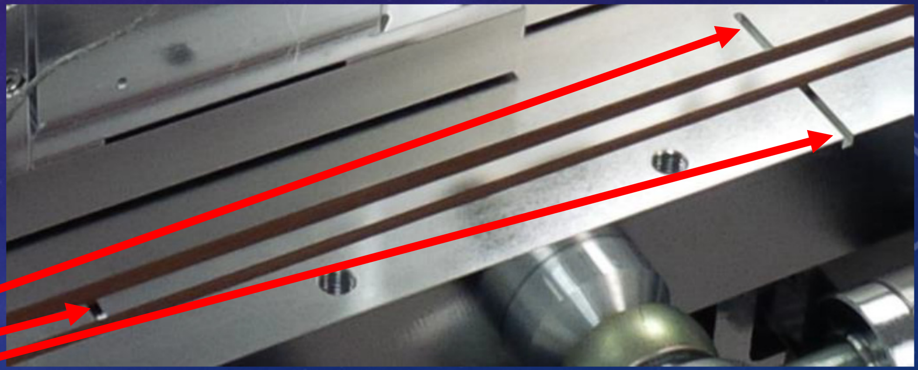

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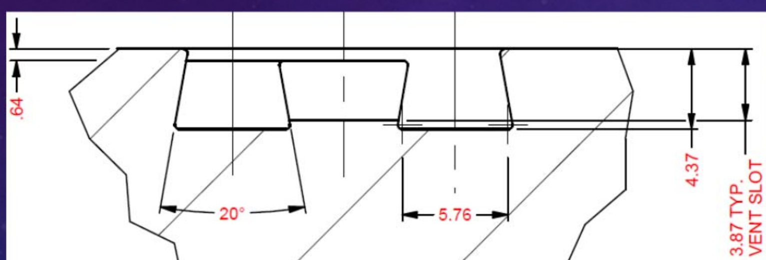
10^{-8} 10^{-3} Atm

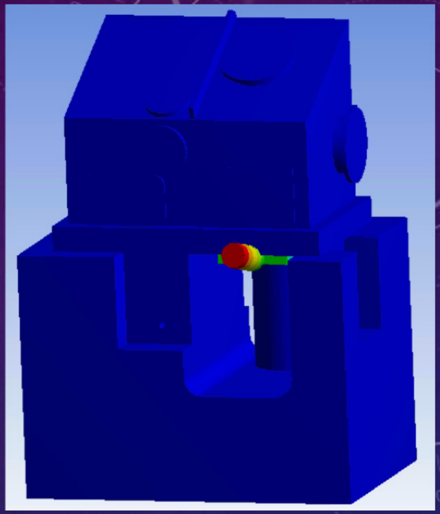


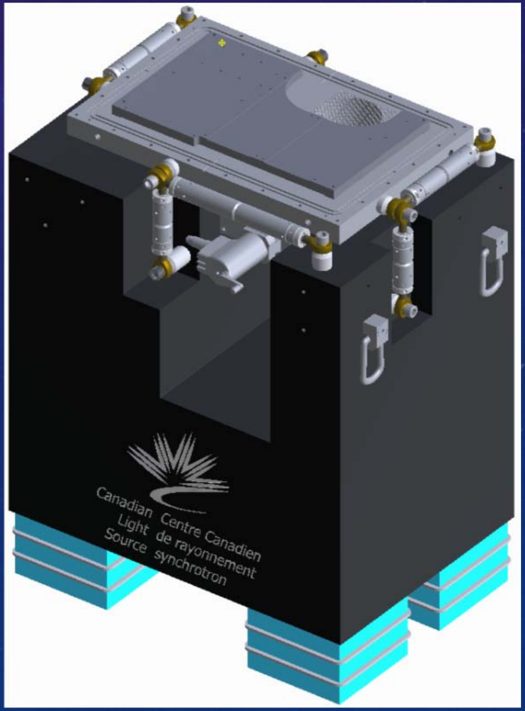
Dovetail Vents

7.7×10^{-9}

Design Problems and Solutions

- Vibration:
  - Spec: < 5 nm RMS
  - Zanite block
    - High stiffness with low mass = high ω_n
    - Almost all vibrational energy < 200 Hz





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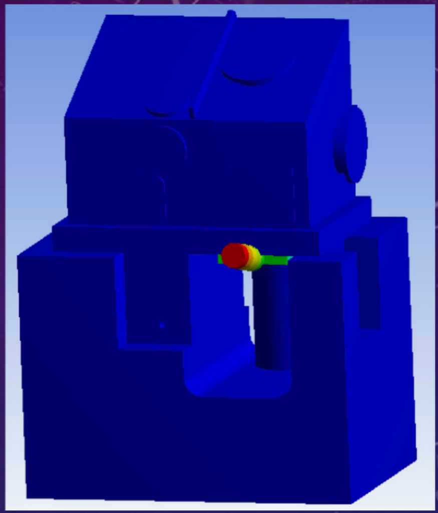

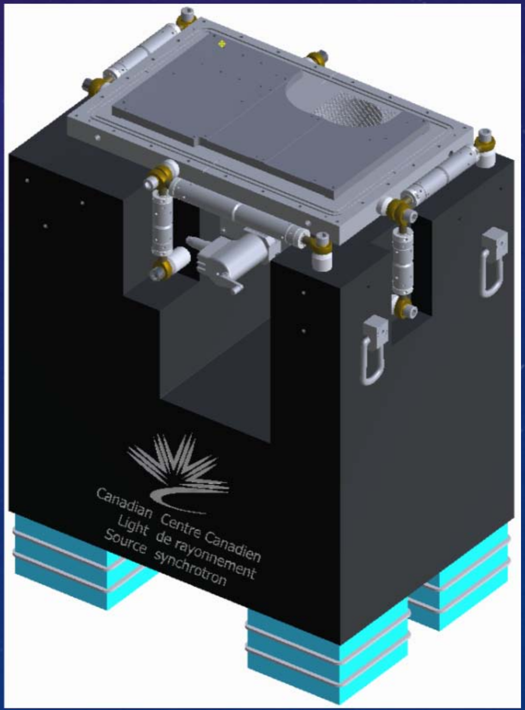

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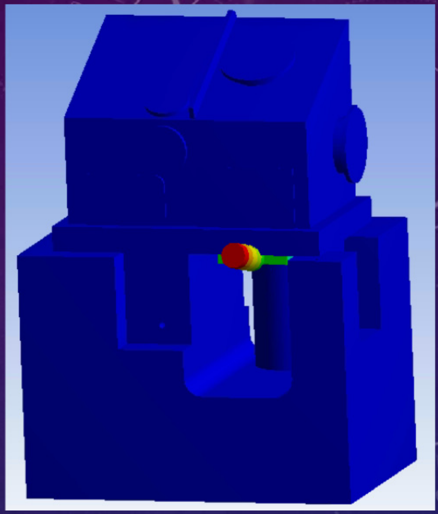

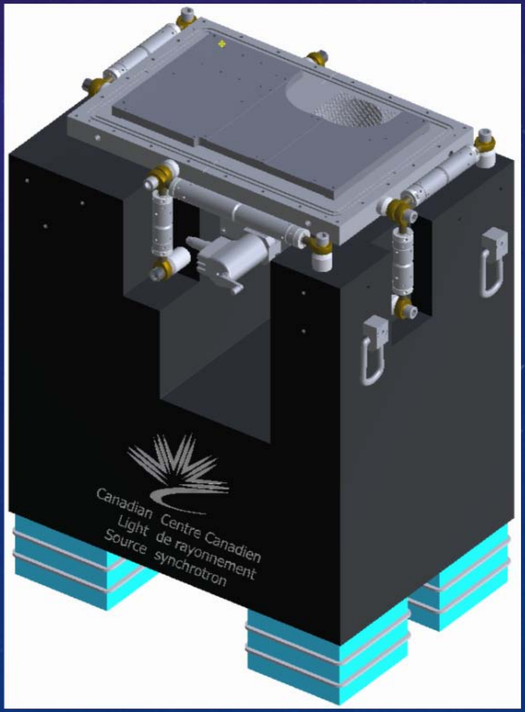

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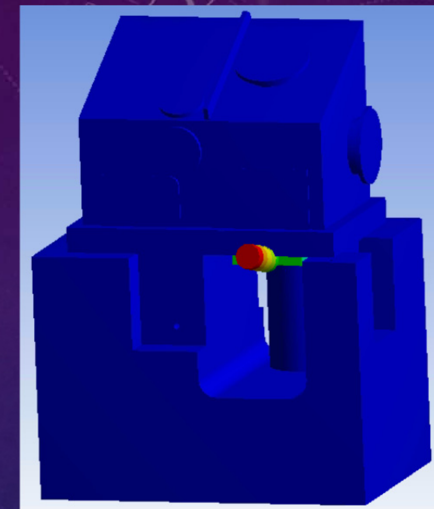

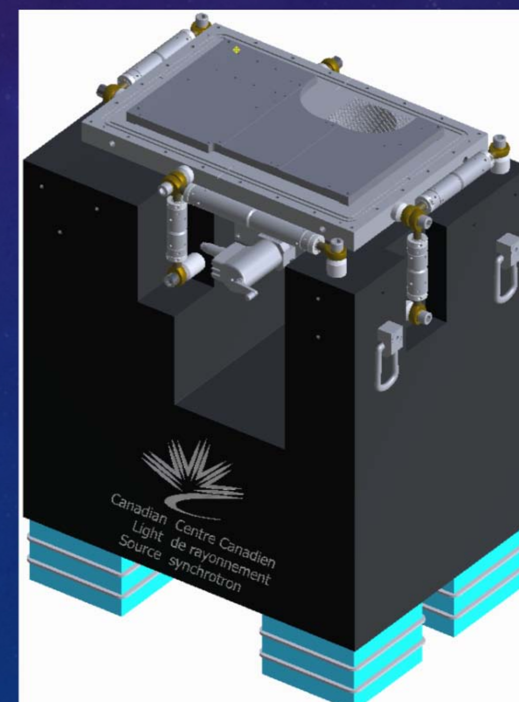

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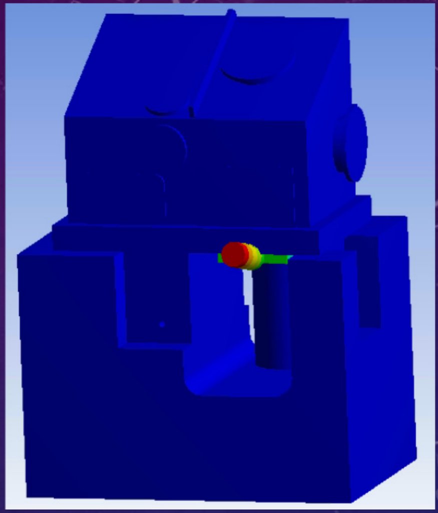
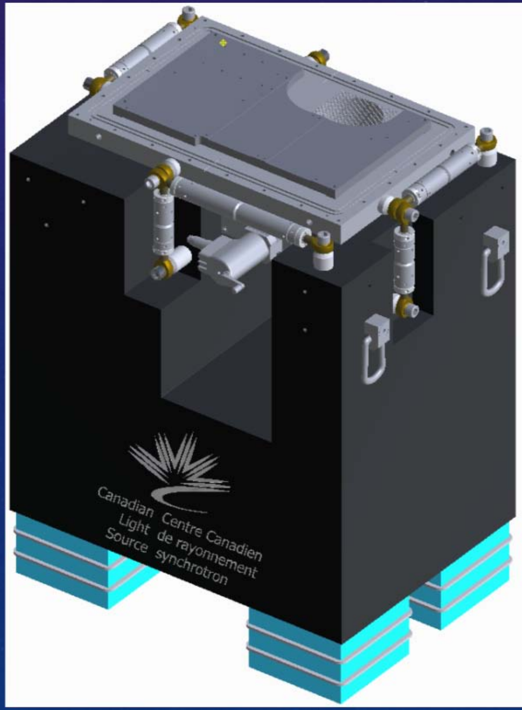
Condition	RMS Amplitude X	RMS Amplitude Y
Rm 1070 on Al blocks, OL	400	400
Rm 1070 on Styrofoam, OL	100	100
Rm 1610.3 on Styrofoam , OL	12	20
Rm 1610.3 on Styrofoam, CL	0.9	0.8





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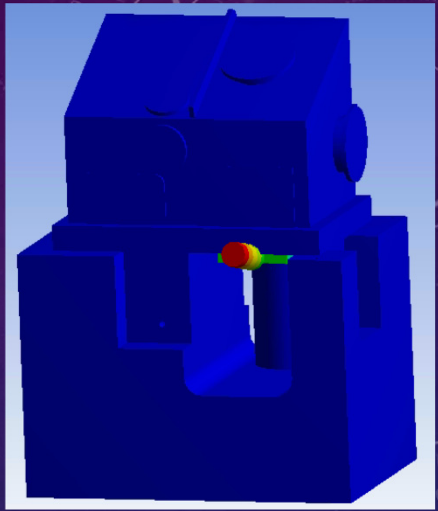

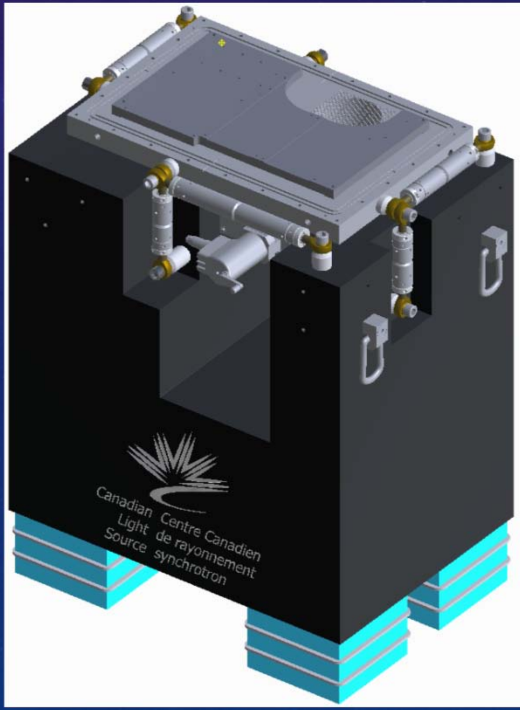

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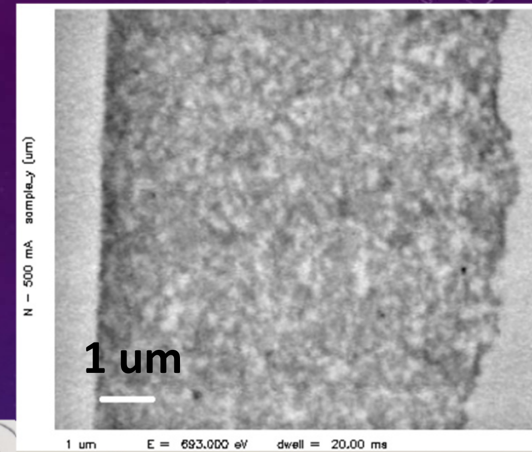
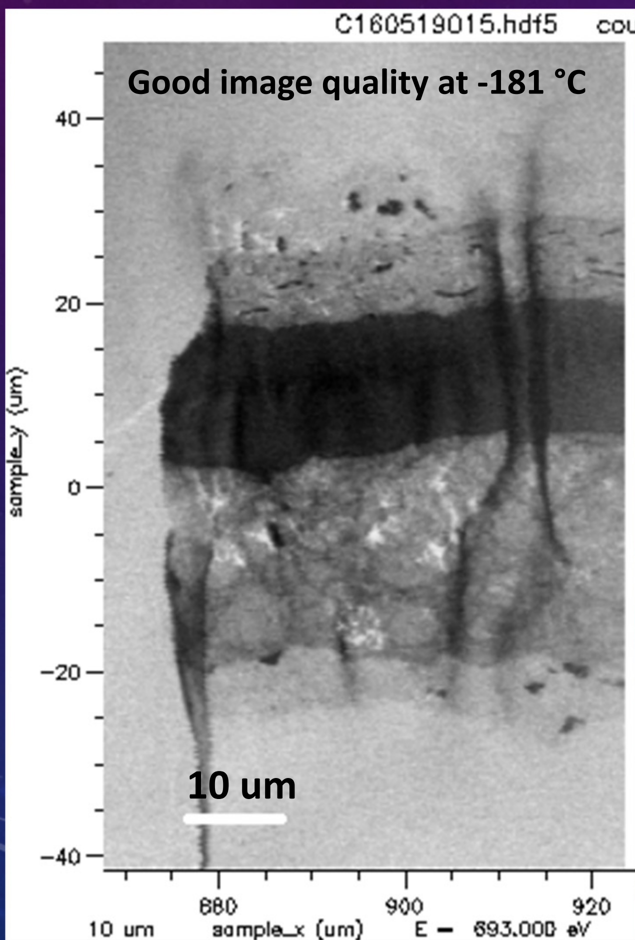
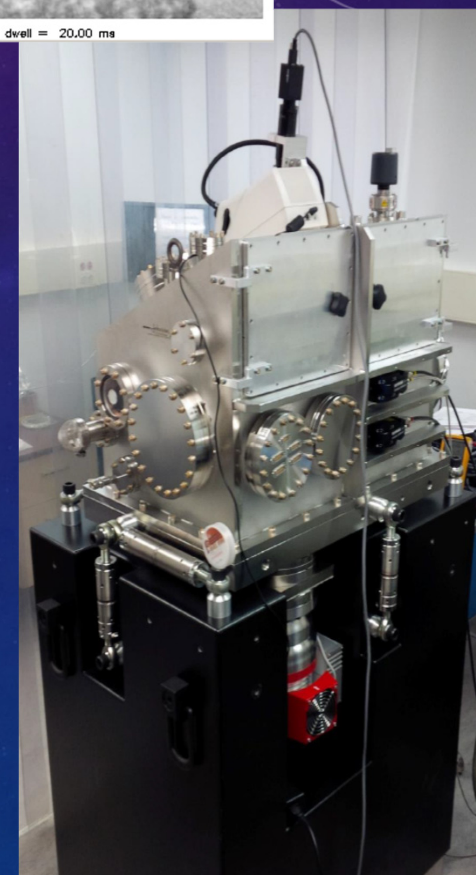
Final Result

- 30 nm spot size achieved!
- All parameters met or exceeded







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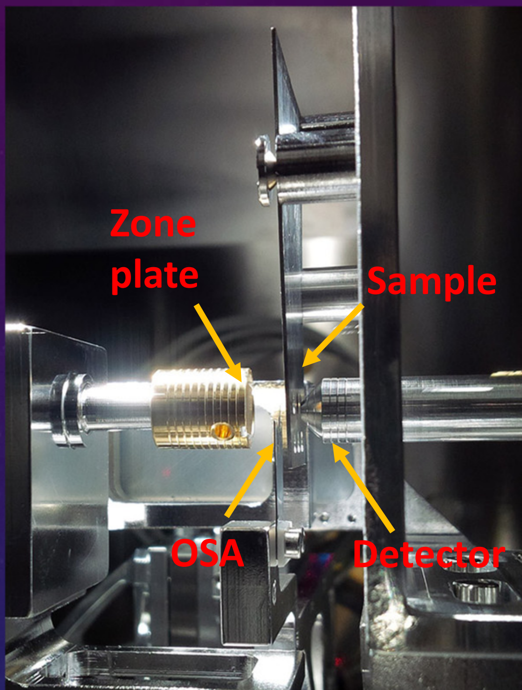

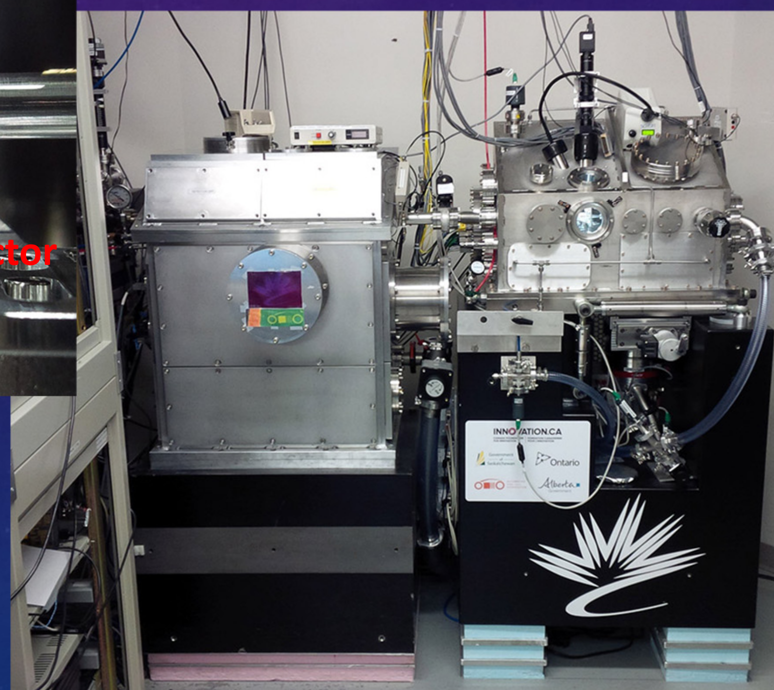

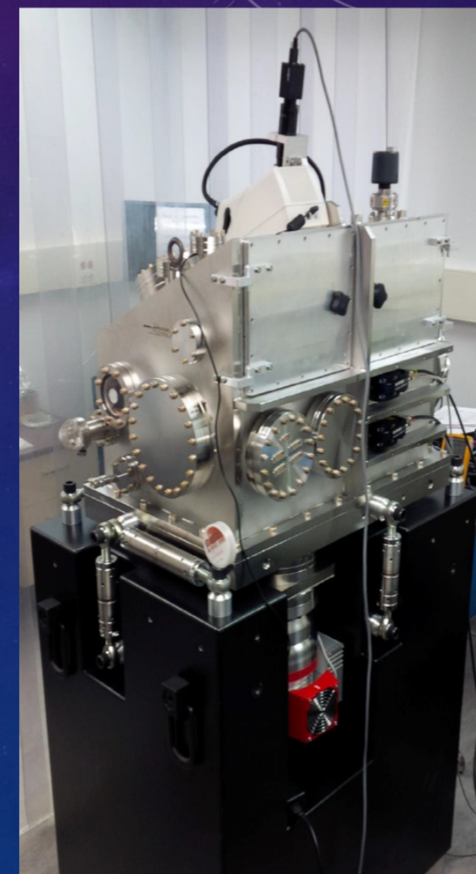

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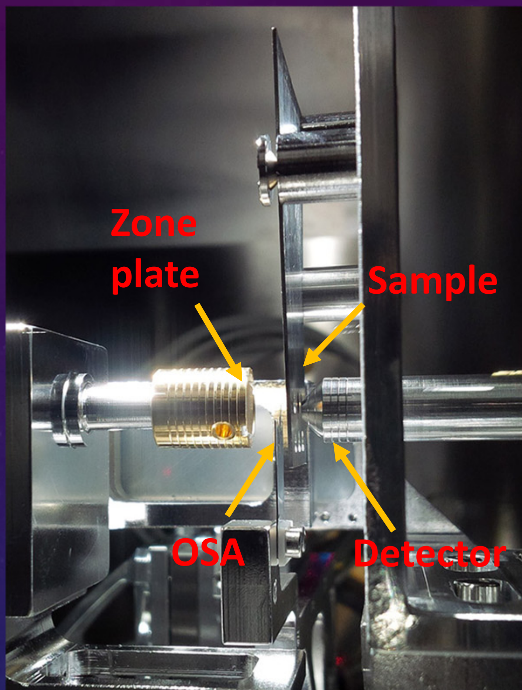

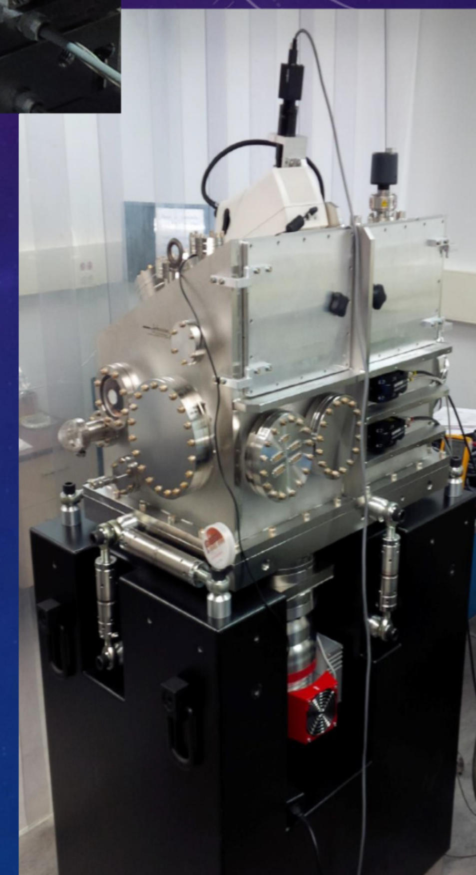

Acknowledgements

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Adam Leontowich (CLS) – Project Delivery.
Darwin Taylor (CLS) – Mech. CAD
Jian Wang (CLS) – Beamline Scientist
John Swirsky (CLS) – Project Manager
Russ Berg (CLS) – Controls
Denis Beauregard (CLS) – Positioning Hardware
Slava Berejnov (AFCC) – Samples

CLS funding partners,


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