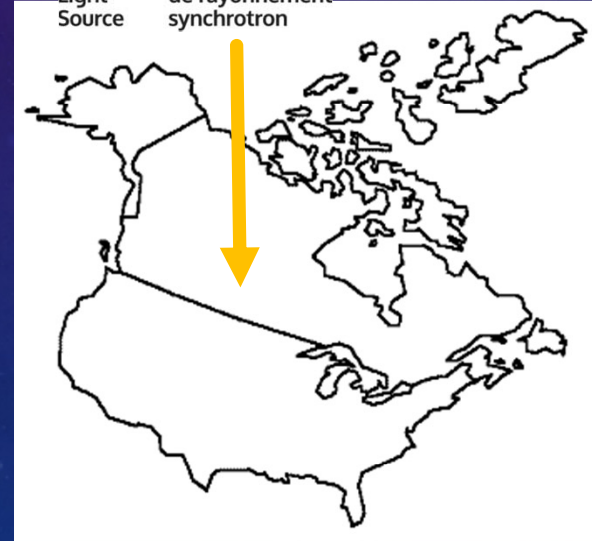
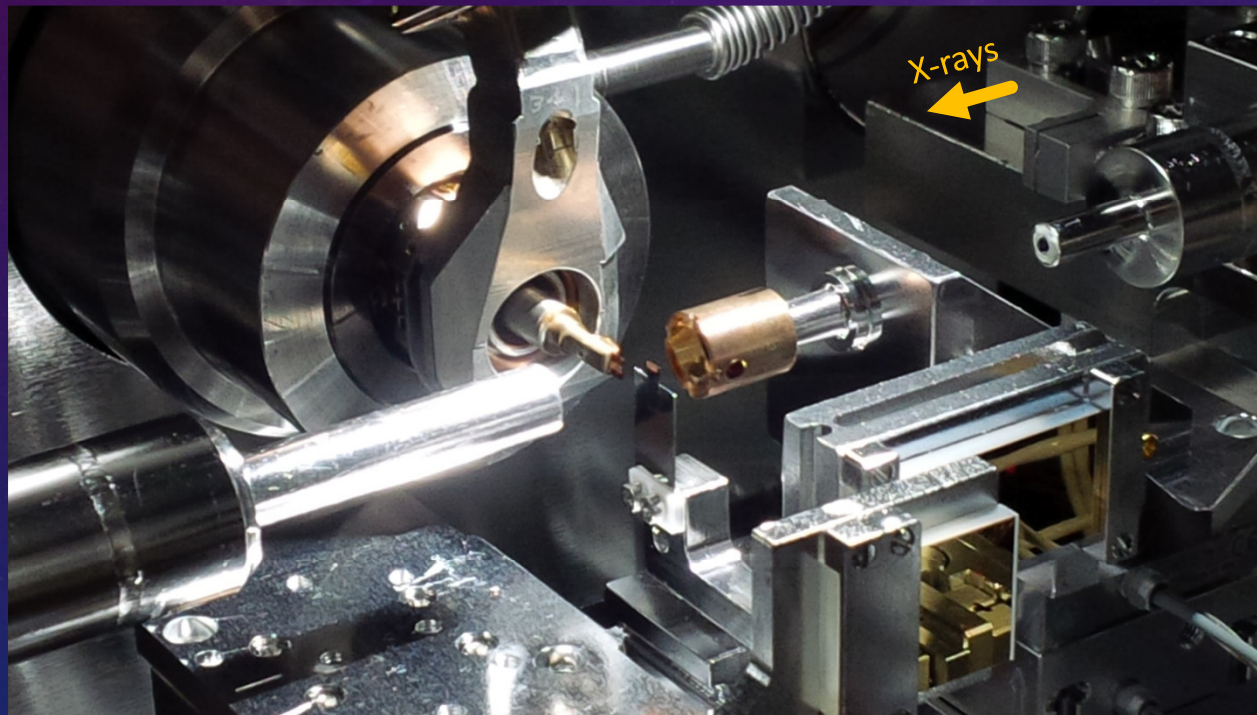


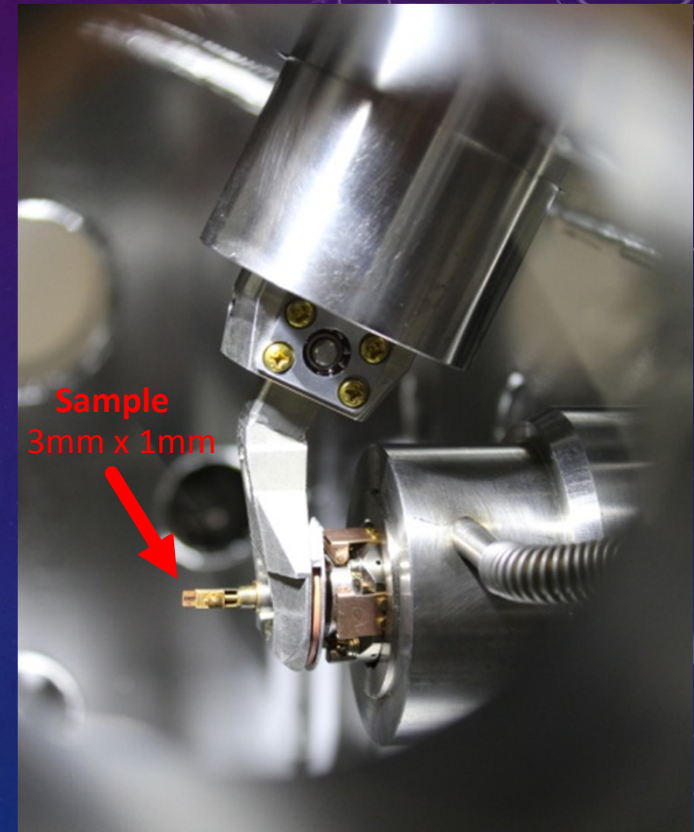
Mechanical Engineering of a Cryo-STXM at CLS

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



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



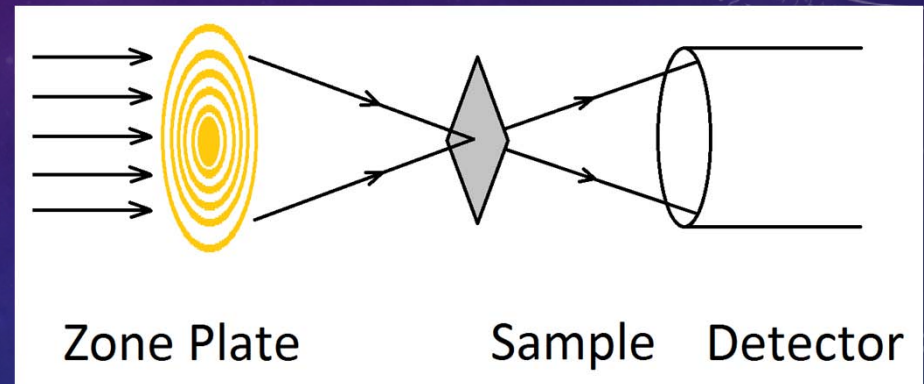
The SM Beamline at CLS

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



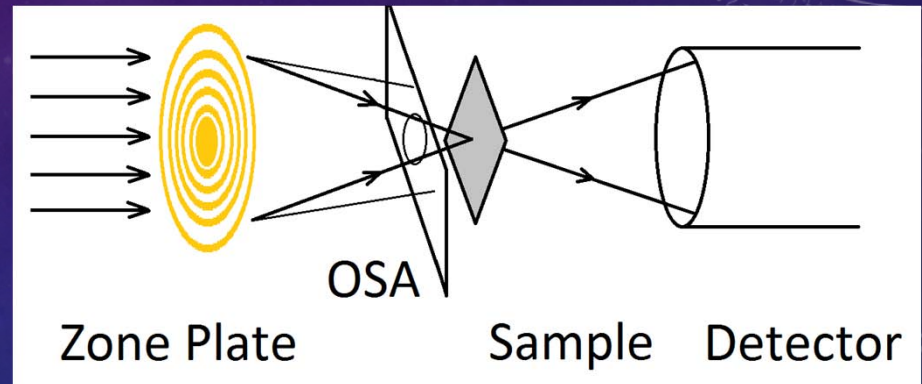
STXM Basics

- 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

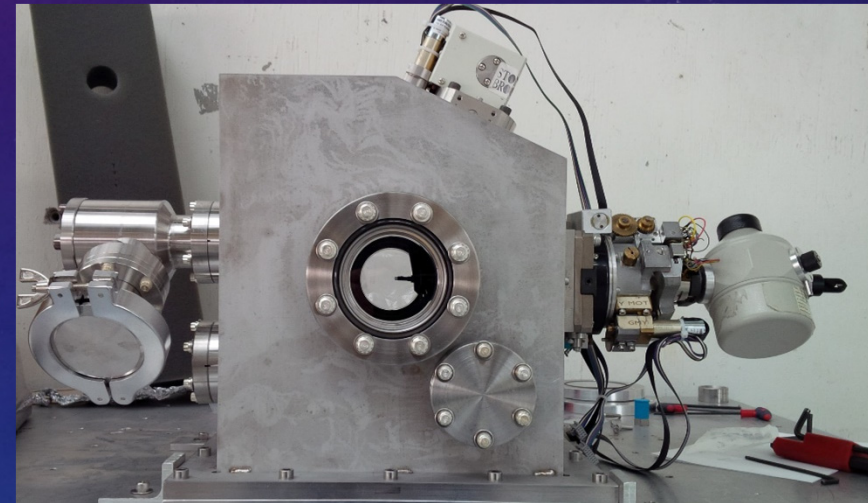
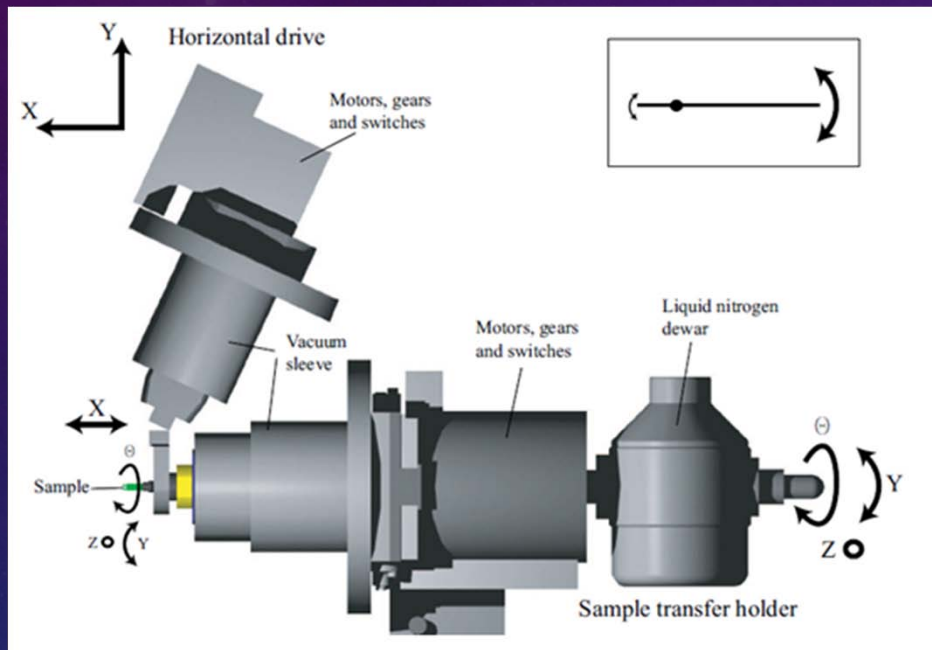
Cryo-STXM Parameters

Vacuum Level	$\leq 10^{-8}$ 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 μ m
Sample Rotation	$\geq \pm 70$ deg

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

Goniometer

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

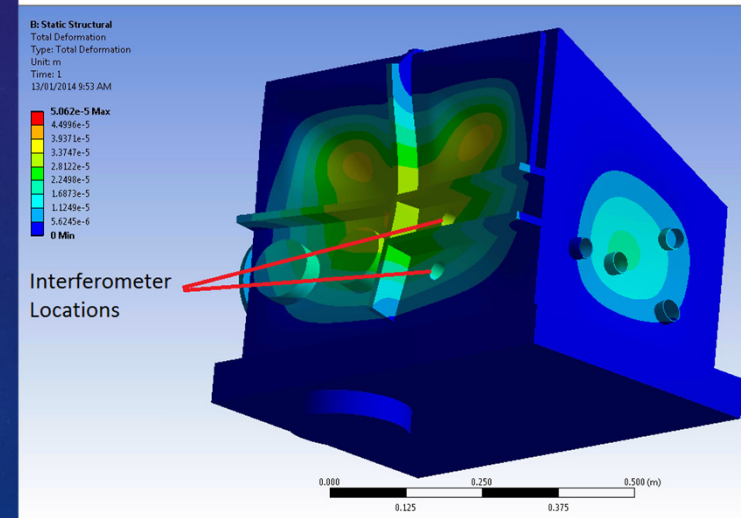
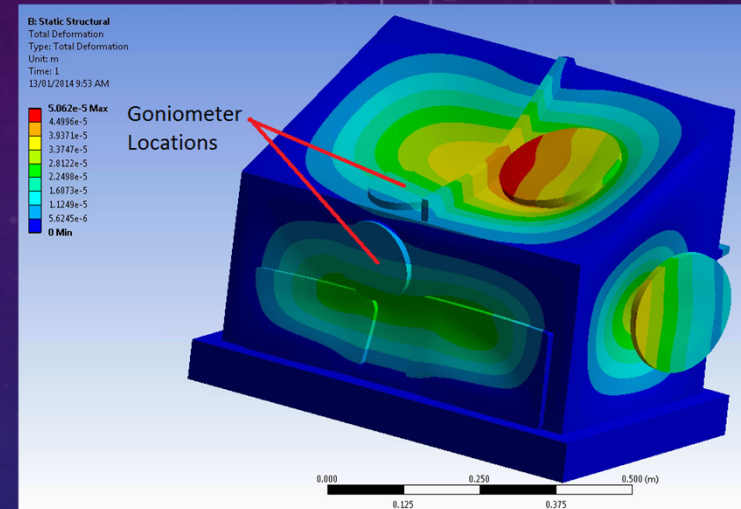
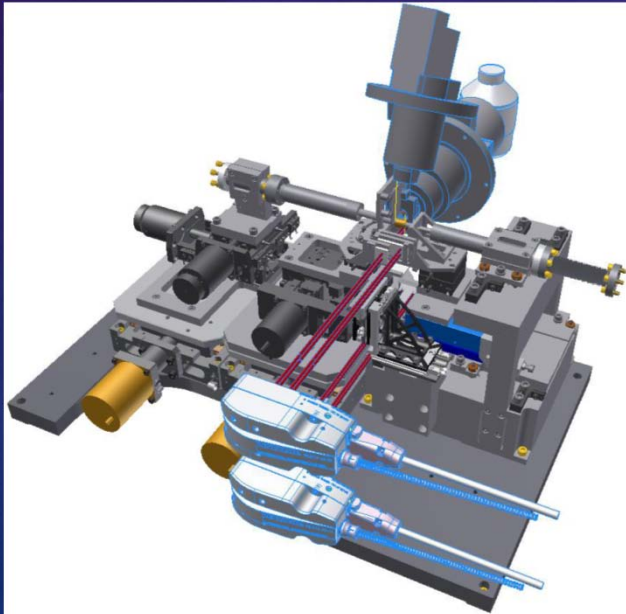


From: T. Beetz, "Soft X-Ray Diffraction Imaging With and Without Lenses and Radiation Damage Studies," Ph.D. Thesis, Physics Dept., Stony Brook University, Stony Brook, NY, 2004.

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

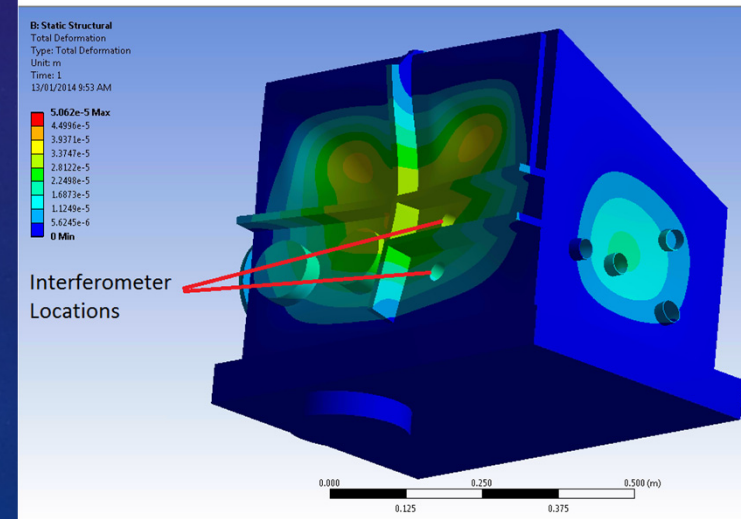
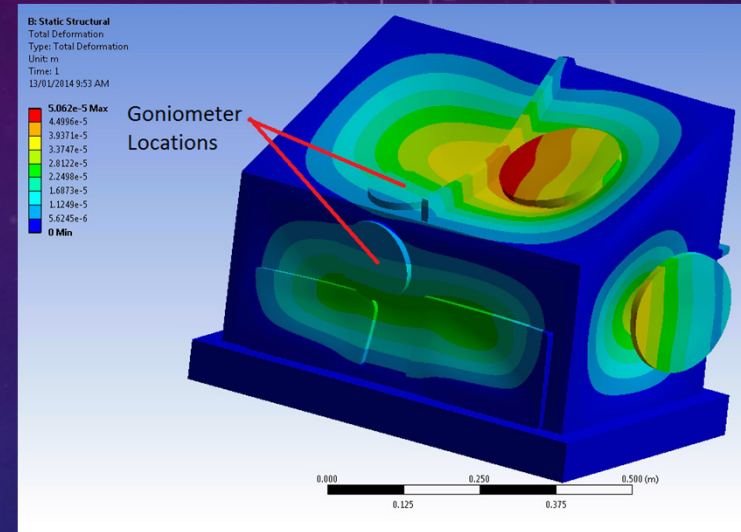
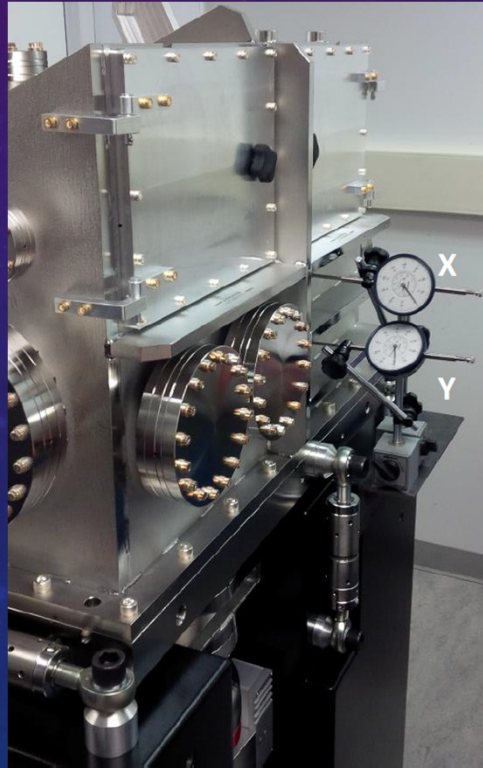
➤ $X = 28 \mu\text{m}$

➤ $Y = 15 \mu\text{m}$

➤ Actual

➤ $X = 29 \mu\text{m}$

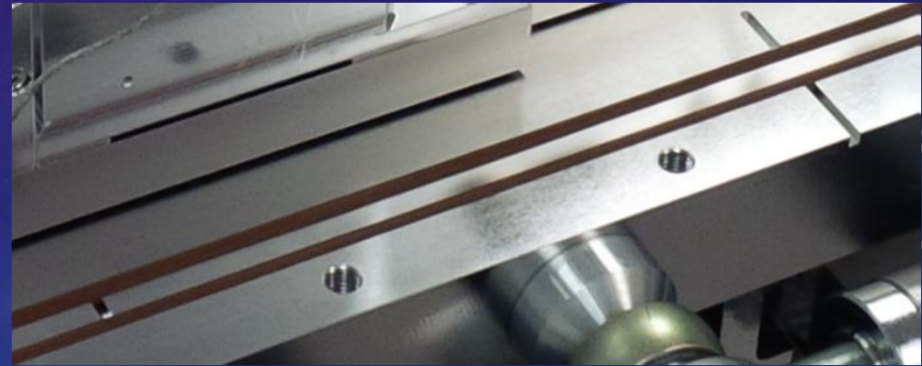
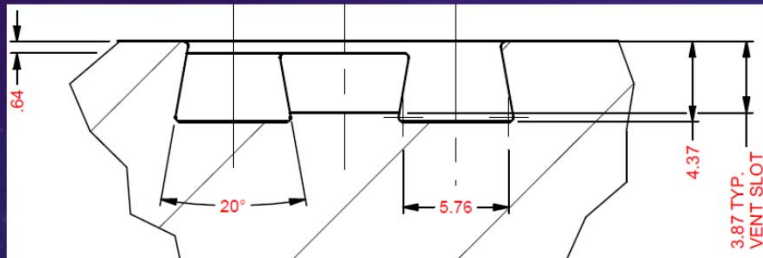
➤ $Y = 25 \mu\text{m}$



Design Problems and Solutions

➤ Vacuum:

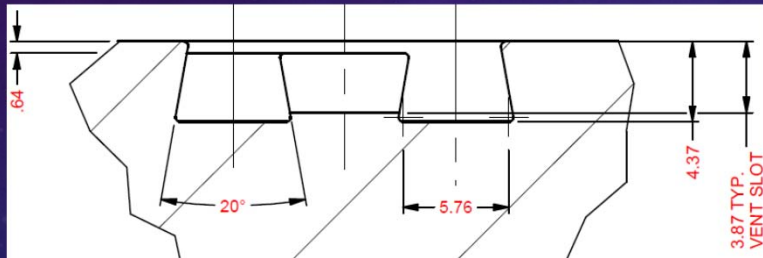
- Conflats where possible
 - Can't open often
 - Limited size/shape
- O-rings for other seals
 - Double O-ring with differential pumping



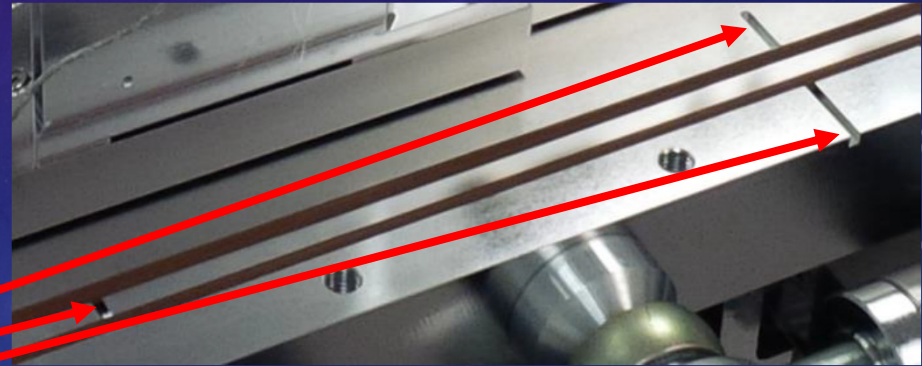
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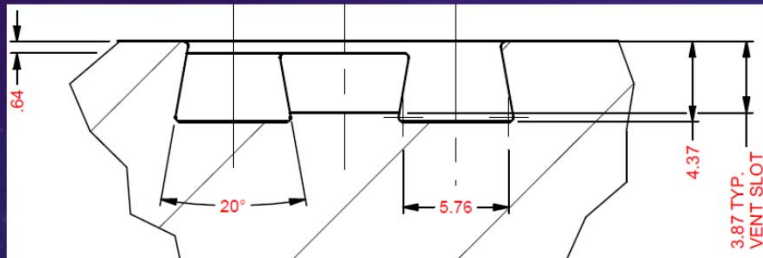
Dovetail Vents



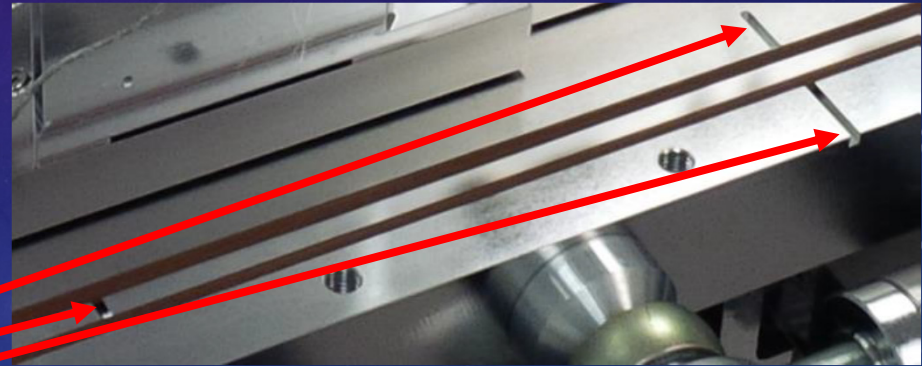
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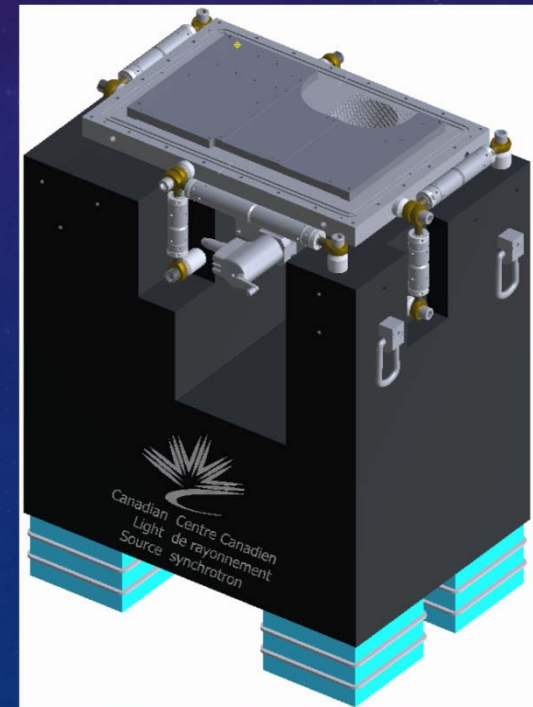
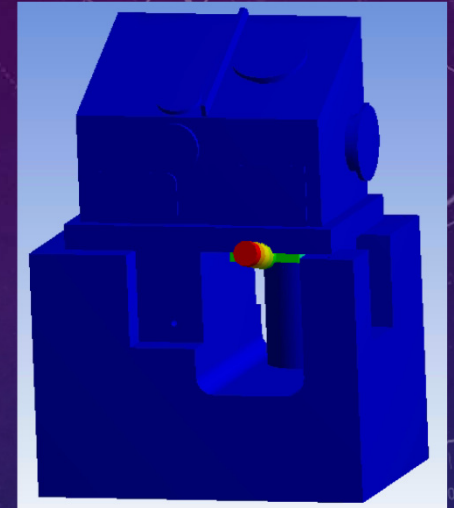


7.7×10^{-9}

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

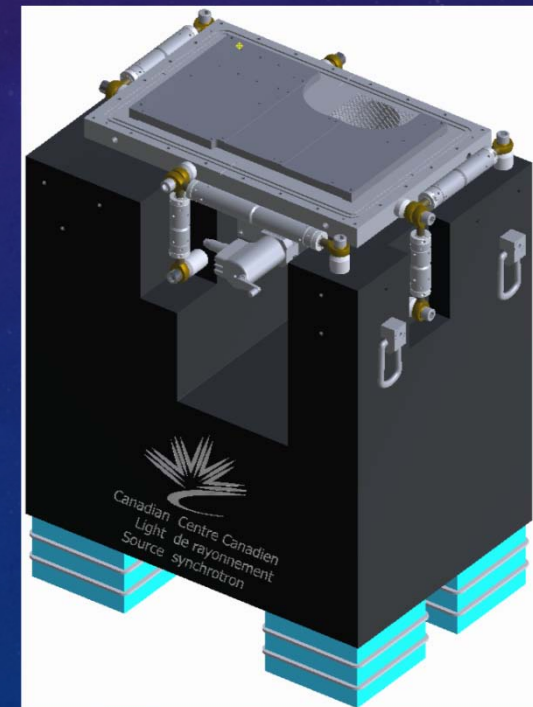
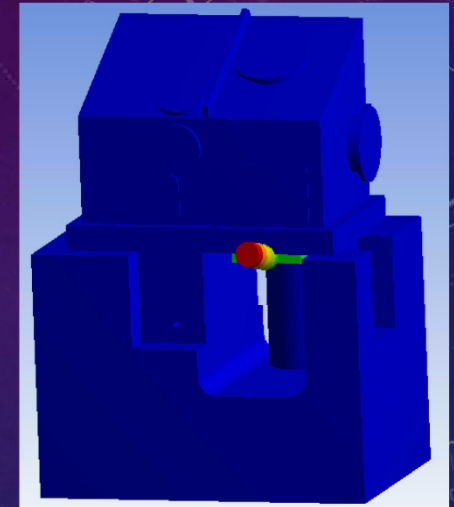


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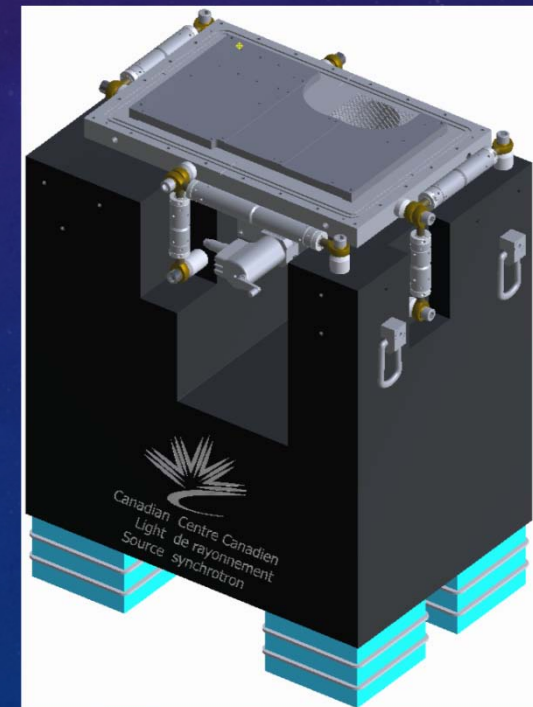
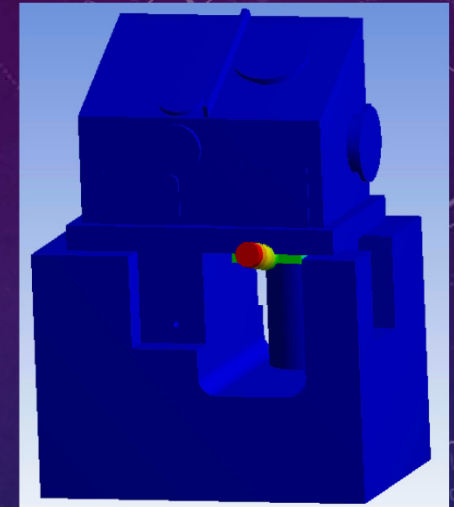
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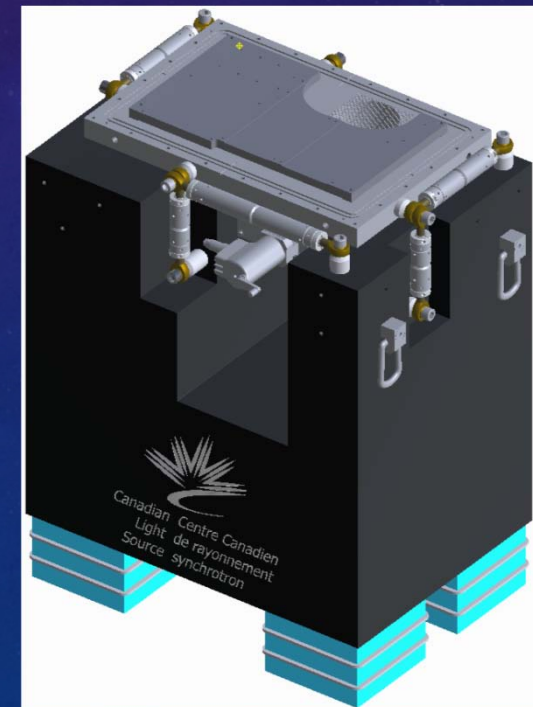
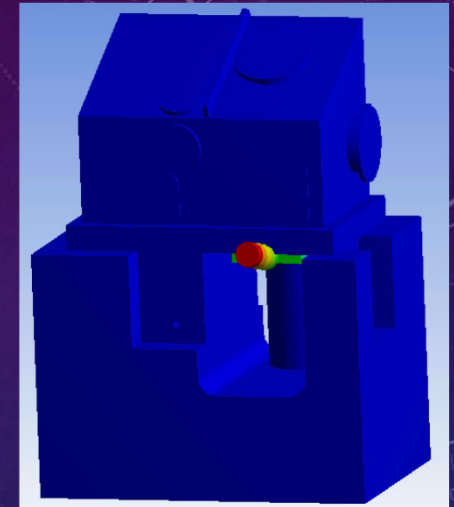
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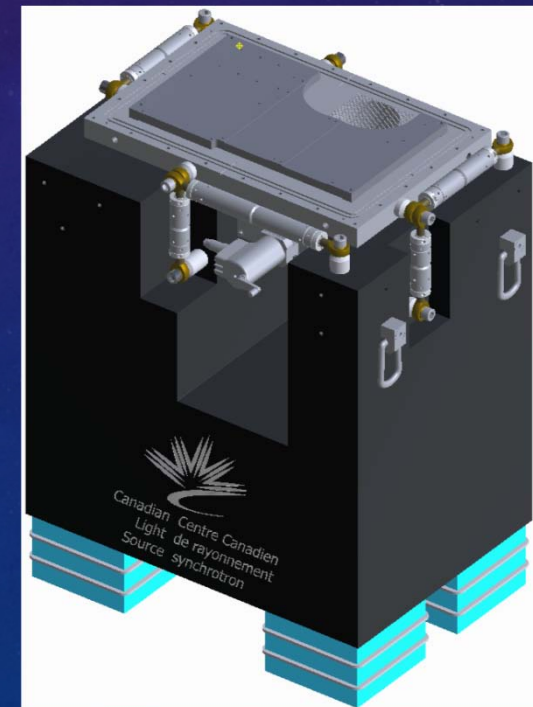
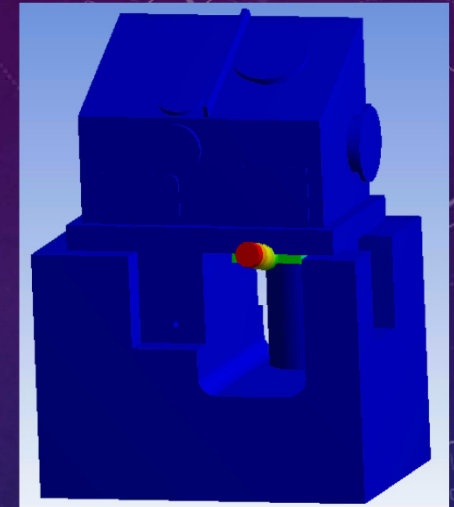
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Condition	RMS Amplitude X	RMS Amplitude Y
Rm 1070 on Al blocks, OL	400	400
Rm 1070 on Styrofoam, OL	100	100
Rm 1610.3 on Styrofoam , OL	12	20
Rm 1610.3 on Styrofoam, CL	0.9	0.8



Design Problems and Solutions

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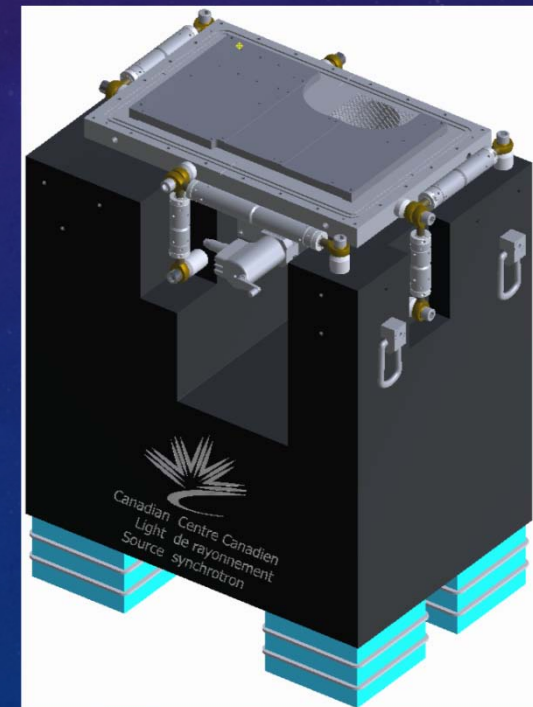
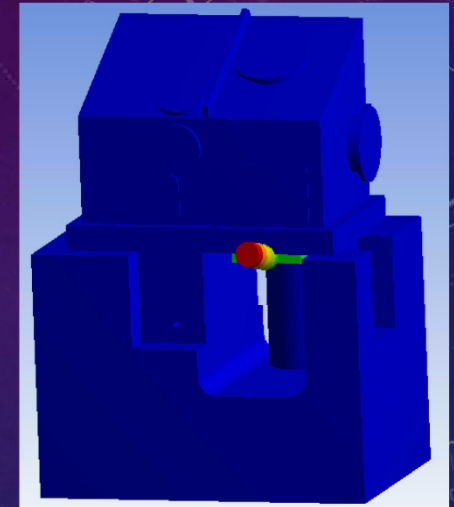
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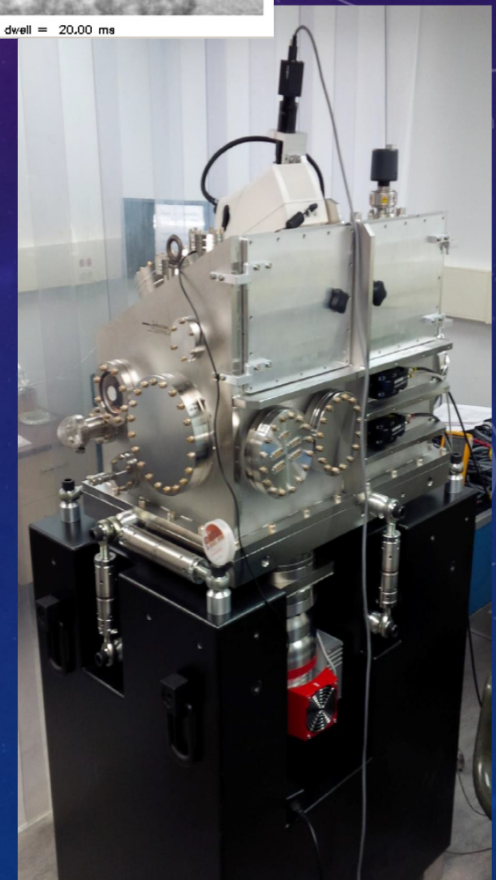
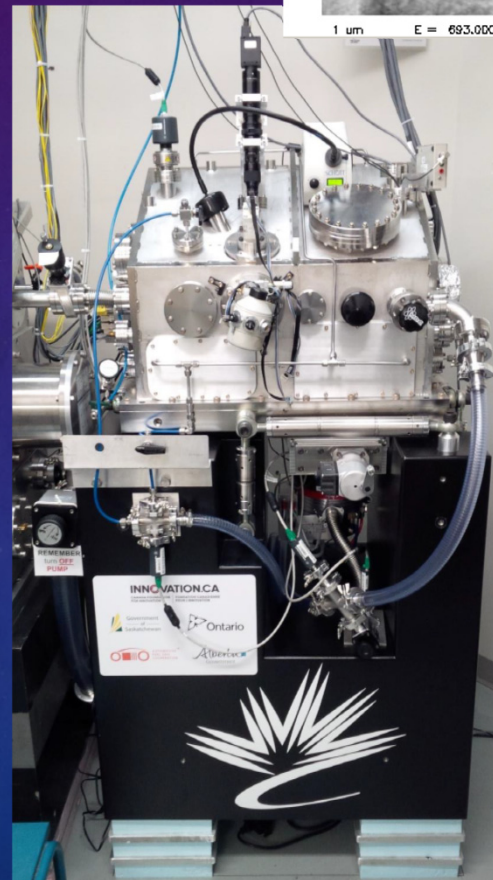
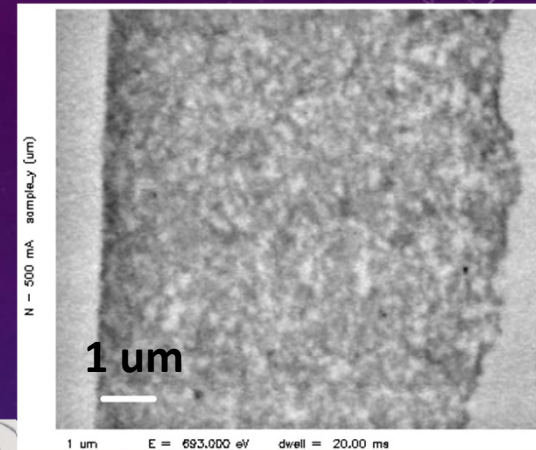
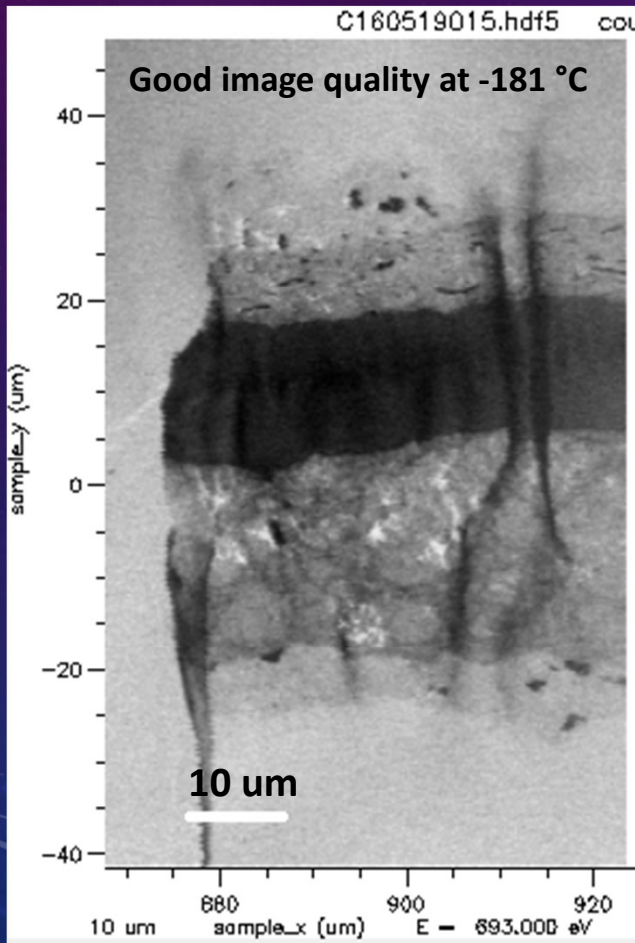
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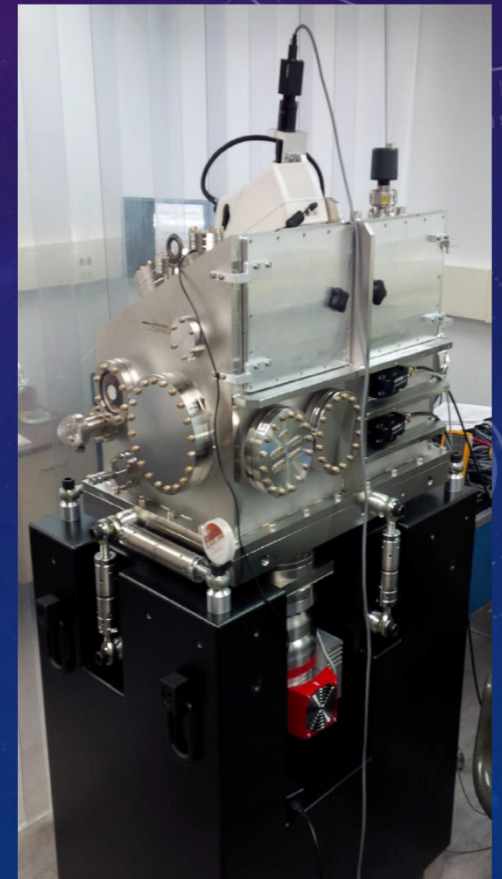
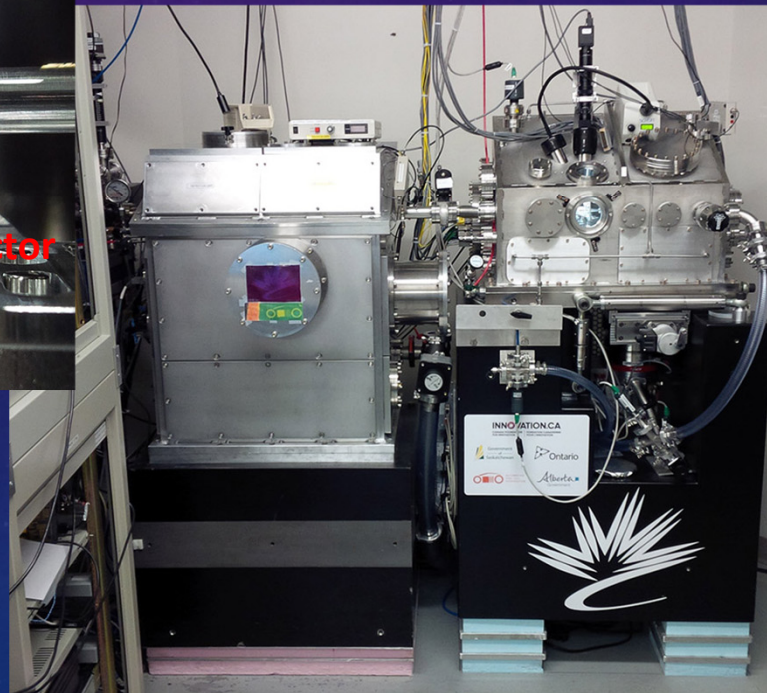
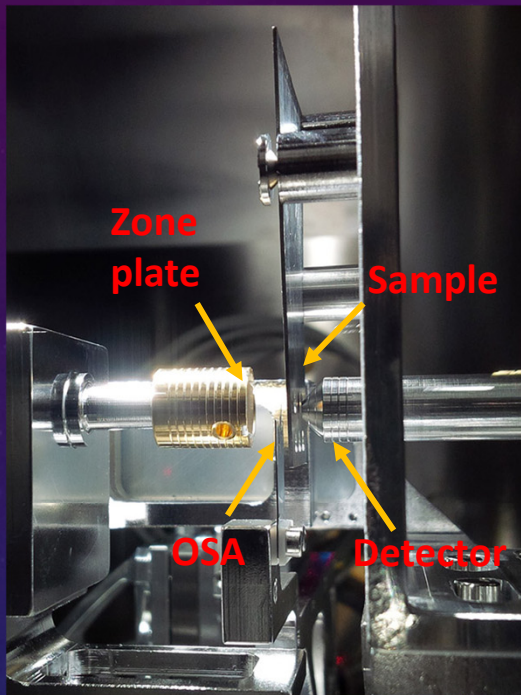


Final Result

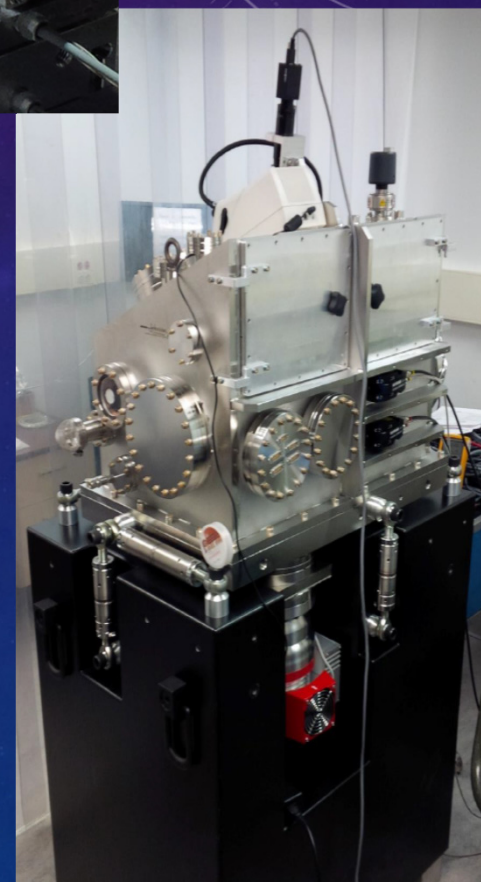
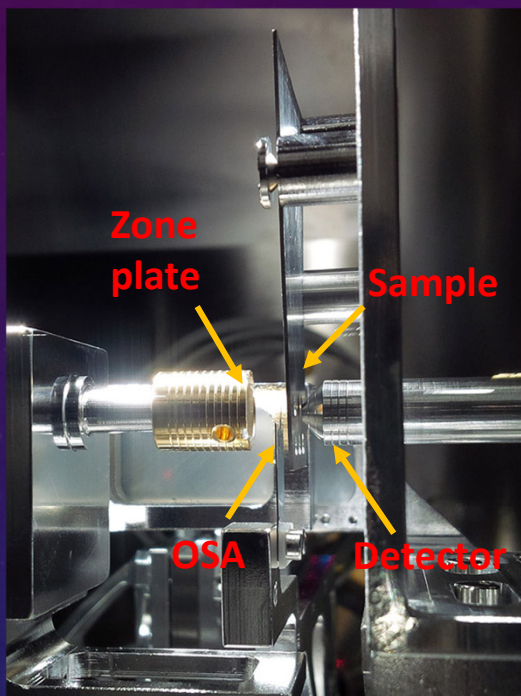
- 30 nm spot size achieved!
- All parameters met or exceeded



Final Result



Final Result



Acknowledgements

CFI Leading Edge Fund, “Enhancing the SM Beamline and Endstations at the CLS”

Stephen Urquhart (Project leader, U. Sask.), Chithra Karunakaran, Adam Hitchcock (McMaster U.)

Cryo-STXM funding partners,

Chris Jacobsen (Northwestern U.) – Equipment

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,





XRM2018

INTERNATIONAL CONFERENCE
X-RAY MICROSCOPY

August 19-24, 2018

Saskatoon, Saskatchewan, Canada