Coherence preserving pseudo channel-cut monochromator at the ESRF Troika beamline.

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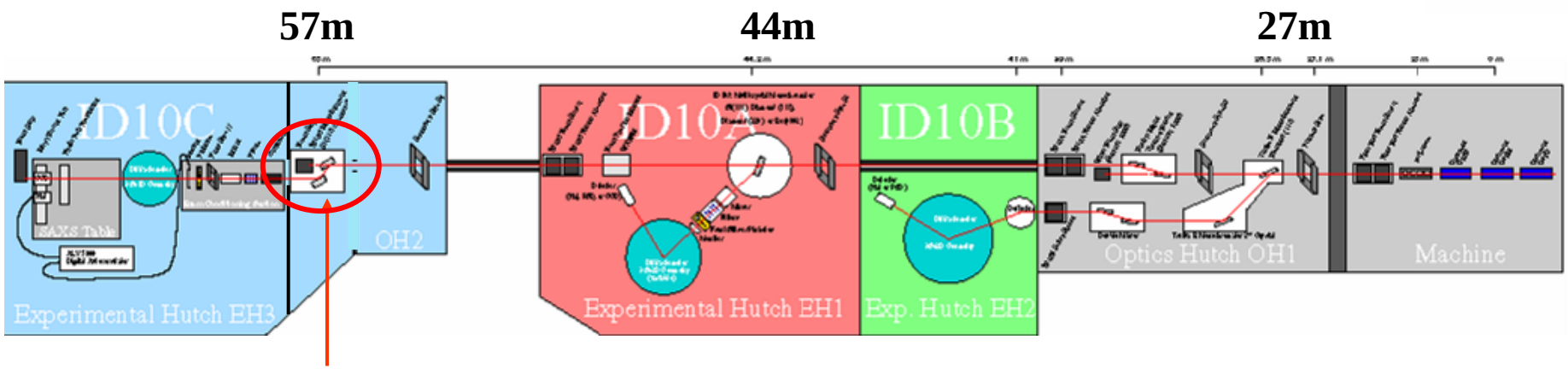
SUMMARY

- **Introduction: The ESRF TROIKA beamline.**
- **“ Channel-cut” versus “pseudo channel-cut” monochromator.**
- **Characterization of the pseudo channel cut.**
- **Conclusion.**

INTRODUCTION: The ESRF Troika beamlines

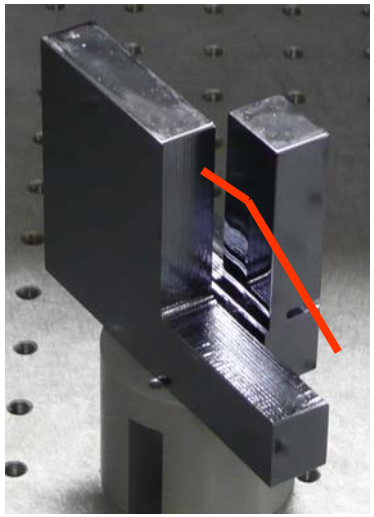


Pseudo channel-cut monochromator

- **X-ray source characteristics:**
  Two U35 and one U27 undulators – High β section.
  Source size 928 x 23 μm^2 (HxV) FWHM
  Source divergence 28 x 17 μrad^2 (HxV) FWHM @ 10keV.

- **ID10C beamline** is mainly dedicated for coherent experiments: XPCS and CDI
  Responsible: Anders Madsen.

THE CHANNEL-CUT MONOCHROMATOR

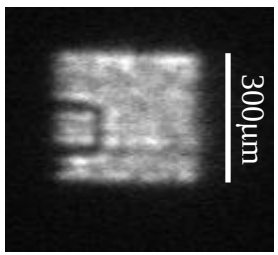


The original Si(111) channel-cut monochromator was operating in horizontal scattering geometry in the E-range 6-22keV.

It was designed for **small white beams.**

Surface preparation : Reflecting surfaces manually polished with a diamond paste and etched.

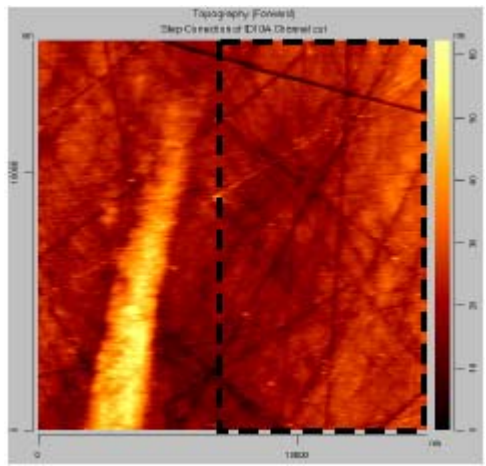
Working fine under small white beams but immediately showing a limited surface quality !



"X-ray eye" image of the Si111 reflection at 8keV

Polishing striations clearly visible in the diffraction image.

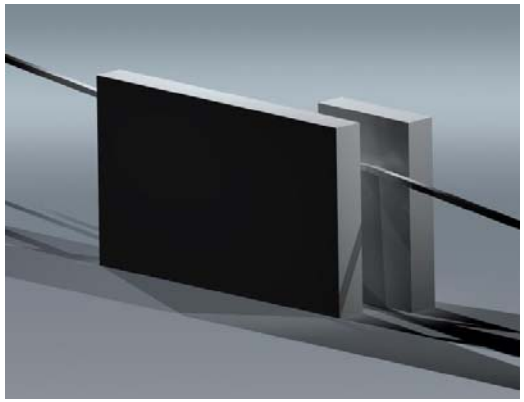
Measured RMS micro-roughness: 36Å (at 50X)



AFM image (A.Rommeveaux)

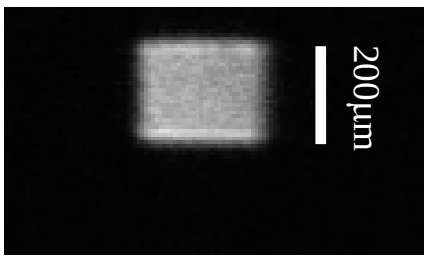
Go to two independent plane Si crystals.

THE PSEUDO CHANNEL CUT MONOCHROMATOR



Replace the monolithic channel-cut by two separate plane Si (111) crystals cut from the same highly polished crystal.

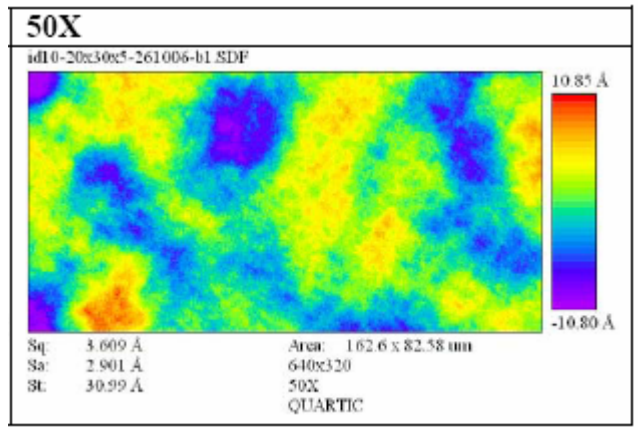
Surface preparation : mechanical-chemical polishing (with silica colloidal solution) with no etching.



First 8keV beam recorded at Troika III

Featureless beam !

Measured RMS micro-roughness:3.6Å, 10 times less than the monolithic device.



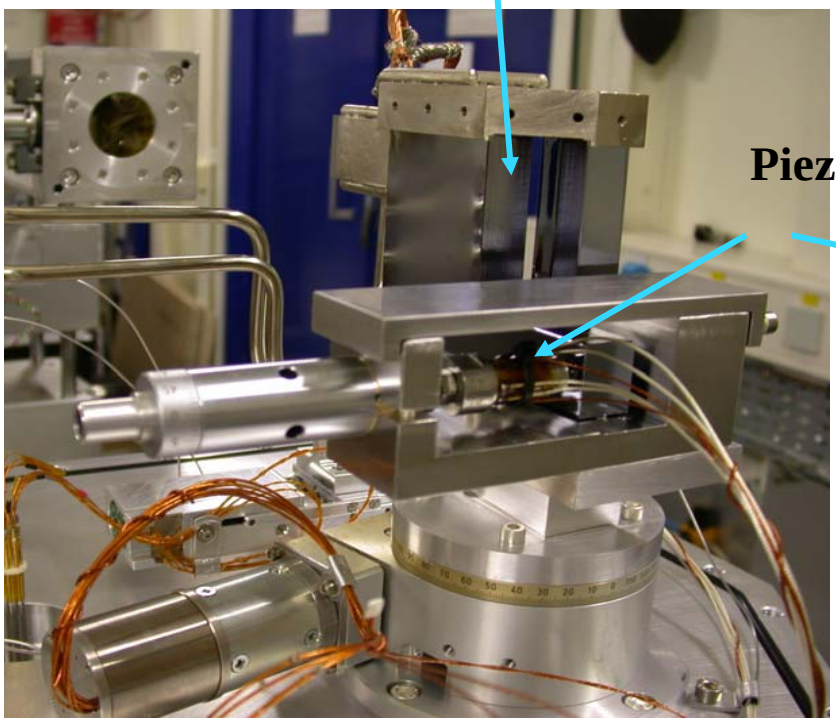
Roughness measurement (A.Rommeveaux)

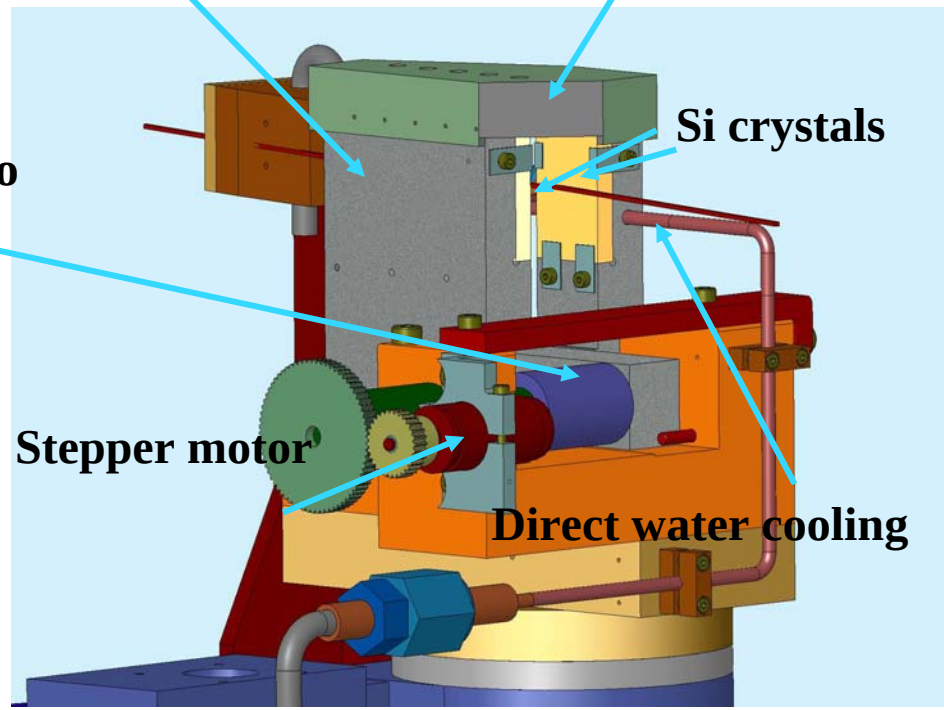
Two independent splane Si crystals do not produce visible phase contrast in the diffraction image.

“Channel-cut” vs “pseudo channel-cut” monochromator.

The channel-cut

The pseudo channel-cut





Which material for the crystals support?

CONSTRAINTS

- ✓ **No strain on the crystal:**
  - → **InGa Eutectic between the crystals and the support.**
  - →**Similar expansion coefficient of the crystal and its support**:

$$\alpha_{Si} \sim \alpha_{Support}$$

- ✓ **High stability in time:**

Whatever the outside thermal fluctuations are. (an experiment may last up to a week)

→ General thermal conduction equation:

$$D\nabla^2 T + (q.C_p^{-1}.\rho^{-1}) = \partial T / \partial t$$

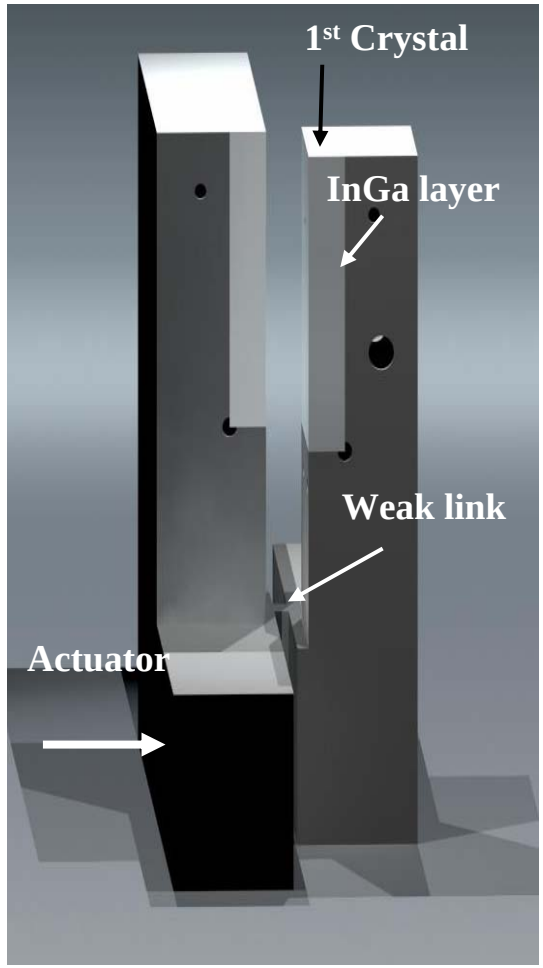
Where $D = k.C_p^{-1}.\rho^{-1}$ is the diffusivity with with **k** the thermal conductivity, ρ the density and **Cp** the specific heat.

If we consider a periodic thermal perturbation, solution is:

$$T = T_0 e^{-\gamma'' x} e^{i(\omega t - \gamma' x)}$$ With $\gamma' = \gamma'' = \sqrt{\omega / 2D}$

→ **The smaller the diffusivity D, the more important the damping.**

→ **In addition expansion coefficient α as small as possible.**



Which material for the crystals support?

✓ **High rigidity** :

No parasitic deformation when we move the actuator.

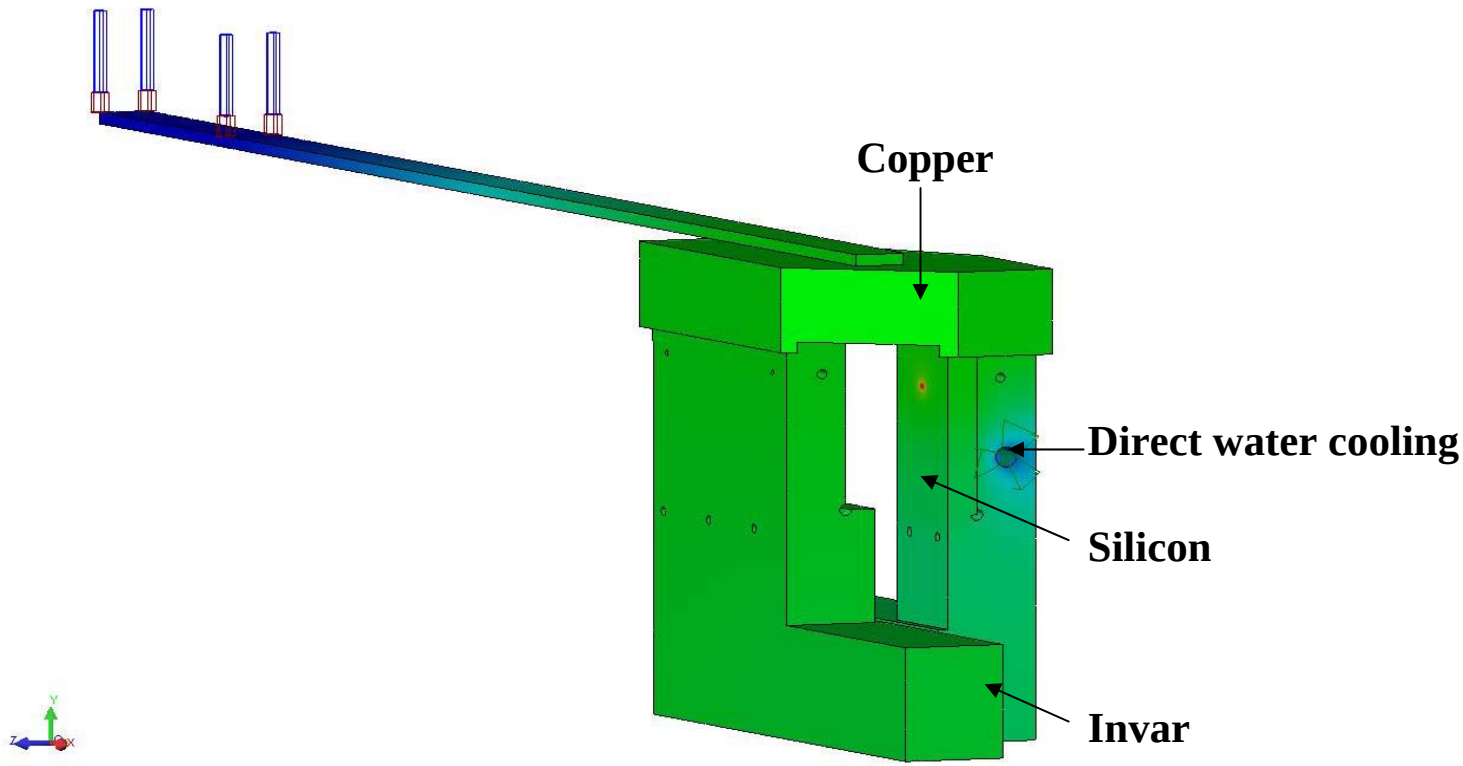
→ **Young modulus E has to be the higher as possible.**

Hooke's law: $\sigma = E \cdot \varepsilon$ with σ the stress, **E** the young modulus and ε the deformation.

Material	Expansion coefficient α ($10^{-6}K^{-1}$)	Thermal conductivity k ($W\ m^{-1}K^{-1}$)	Young Modulus E GPa	Density ρ ($Kg\ m^{-3}$)	Heat Capacity Cp ($J\ Kg^{-1}\ K^{-1}$)	Diffusivity $D = k\ \rho^{-1}Cp^{-1}$ ($10^{-5}m^2\ s^{-1}$)
Si	2.6	149	100	2300	700	9.2
Invar	**1.3**	**13**	**140**	**7800**	**450**	**0.37**
Al	23.5	237	75	2800	900	9.4
Cu	17	401	137	8000	385	13

In this pseudo channel-cut configuration, Invar is the best compromise.

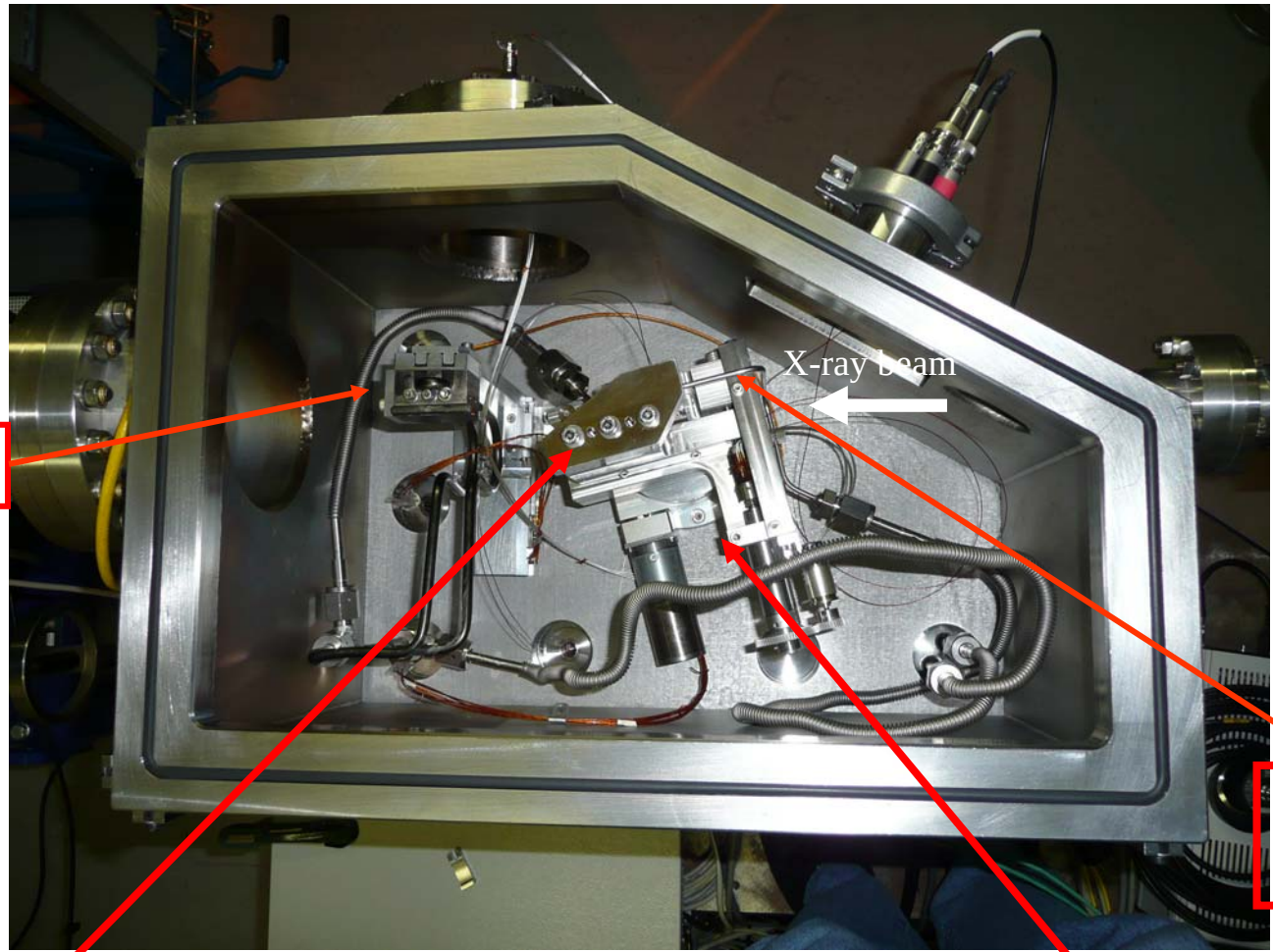
Thermo-mechanical finite element analysis..



PRESENT EXPERIMENT CONDITIONS: 8keV - Normal beam section :0.3 x 0.3 mm
I = 16 bunch / absorbed power = 2W → ΔT over the 1st crystal = 5K ; Slope error = 0.8μrad

EXTREME CONDITIONS:
I = 200mA / absorbed Power = 12W Maximum slope error = 6μrad

The pseudo channel-cut monochromator



Beam Stop

Direct water cooling

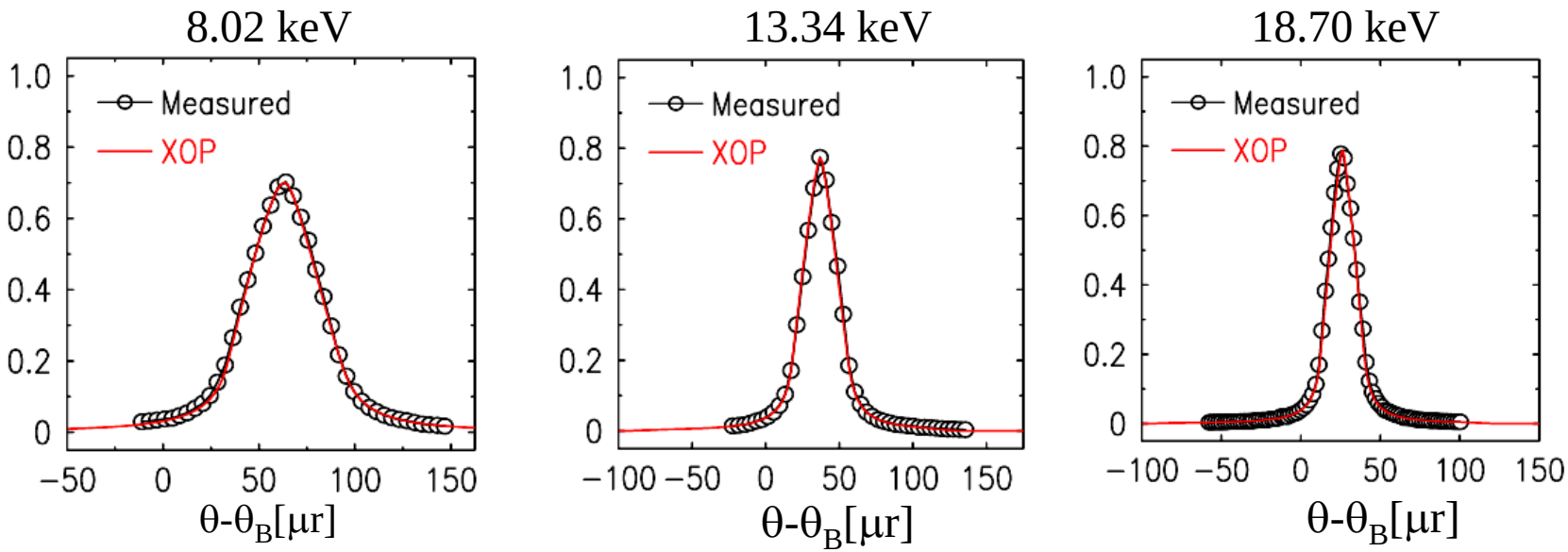
Indirect cooling through the top crystal surfaces

Pseudo channel-cut monochromator

CHARACTERIZATION OF THE PSEUDO CHANNEL-CUT

Tests under real white beam conditions.

300µm beam, IDs tuned for 8 keV, 16-bunch mode, Absorbed power = 2W
Piezo calibration at 8keV: 1µm=39.5µr

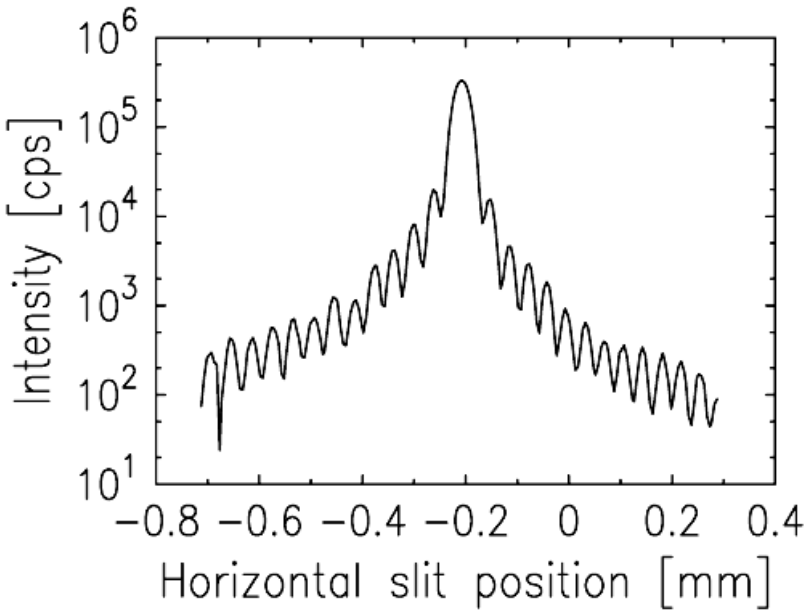


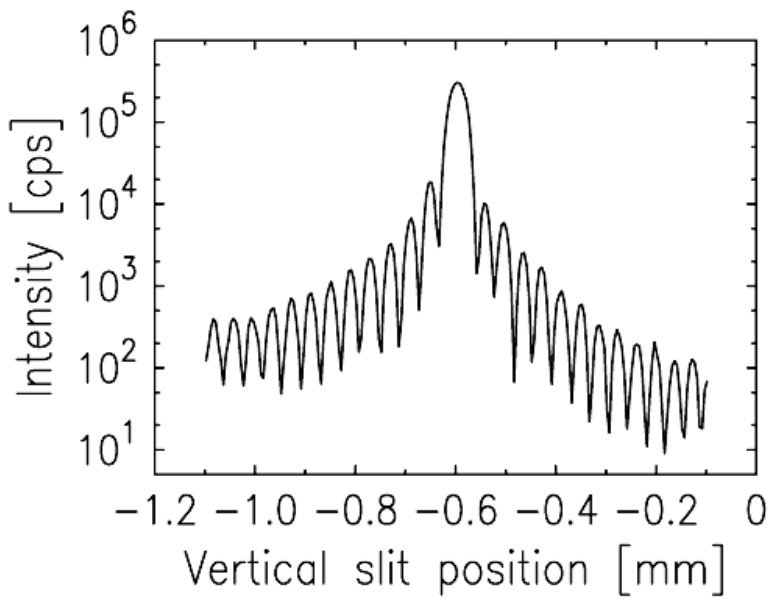
→ **No deformation due to heat load.**

→ **No deformation due to mechanical constraints.**

Coherence preservation: tests under a coherent beam

Airy pattern produced by a 10μm squared pinhole showing nice contrast.





CONCLUSION

Optical quality of the optics is a main issue for X-ray coherent experiments.

DESIGN

Limitation of the surface quality of the channel-cut due to the complex shape.

→ Consider separate plane crystals.

Mechanical stability of a channel-cut remains a great advantage.

→ Design a "pseudo channel-cut".

PERFORMANCES OF THE PSEUDO CHANNEL-CUT

Adjustment of the 2nd crystal with the piezo does not induce parasitic deformations of the crystal surface.

Invar material for the support is definitively the best compromise .

The X-ray characterization confirmed the efficiency of this device.

FUTURE

Update the device and design a UHV compatible pseudo channel-cut to remove the Be windows on both sides.

Transform it into a vertical scattering geometry.

Acknowlegments

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The ESRF optics laboratory:	**Amparo ROMMEVAUX.**

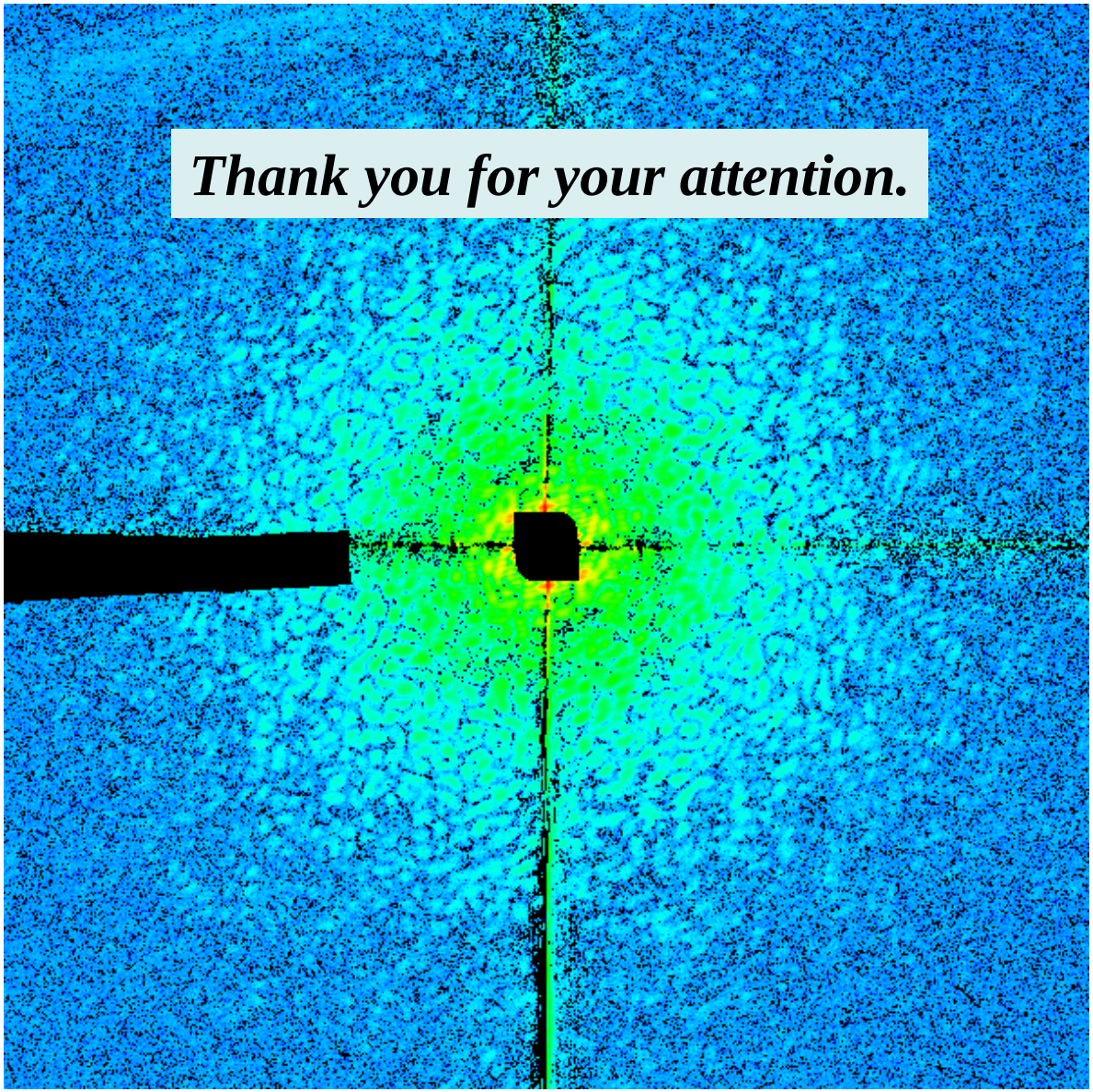

Figure 2: Coherent diffraction patterns (speckle images) of unstained *Deinococcus Radiodurans* bacteria, imaged with the pseudo channel-cut at 8 keV X-rays - Enju Lima . ESRF ID10C – 2008.