THE ANATOMIX BEAMLINE TRANSFOCATOR

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MAIN FEATURES OF ANATOMIX

- Undulator BL on canted section shared with NANOSCOPIUM
- Long beamline (200 m), longest at SOLEIL
- Energy range from 5 to 25 keV

- Two experimental hutches:
  - Hutch 1: X-ray microscopy;
- Beam size: 10 x 6 mm\(^2\) (without optics);
  up to 40 x 6 mm\(^2\) (with optics).
- Beam modalities:
  - Double-crystal mono ($\Delta E/E \approx 10^{-4}$);
  - Double-multilayer mono ($\Delta E/E \approx 10^{-2}$);
  - Filtered white beam.
ANATOMIX BEAMLINE FOOTPRINT

- **Existing synchrotron building**
- **Extension building**
- **Nanoscopium hutches**
- **Anatomix hutches**

**Hutches and Facilities**
- Mirror hutch OH3
- Monochromator hutch OH4
- Experimental hutch EH3 (microscopy)
- Experimental hutch EH4 (parallel-beam tomo)
- Shared “front-end” optics hutch OH1

**Distances**
- 20 m
- 32 m
- 47 m
- 170 m
- 200 m
Focusing modes:

- None
- Mirror (horiz. focusing)
- Secondary source creates wide beam (17–25 keV, tomography in EH2)
- Be CRLs (2D focusing)
- Collimation concentrates beam – (11–25 keV, tomography in EH2)
- Be CRLs (2D focusing)
- Collimation concentrates beam – (5–18 keV, microscopy in EH1)
• "Coherence slit"
• Primary slits

**TRANSFOCATOR**

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**Front-End Hutch**

- Double mirror (removable)
- Transfocator
- Secondary source slit

**Mirror Hutch OH3**

- Double mirror (removable)
- Transfocator
- Secondary source slit

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**Monochromator hutch OH4**

- Secondary slits
- Double-multilayer monochromator (DMM), \( d = 2.5 \text{ nm} \)
- Double-crystal monochromator Si(111)

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**Experiments Hutch EH3**

- Transmission X-ray microscopy
- Zernike phase contrast

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**Experiments Hutch EH4**

- Parallel-beam microtomography
A « transfocator » is a device focusing an X ray beam in both horizontal and vertical axis. It is based on the use of a stack of refractive beryllium lenses (CRL) working by transmission.

Parabolic profile
$R=0.5 \text{ or } 1 \text{mm}$

Credit: B.Lengeler RXOPTICS
Calculations: Thierry Moreno, SOLEIL Optics Group

Intensity distribution in EH3 (microscopy hutch) with optimized number of lenses and Si(111) monochromator
2 groups of lenses (maximum 20 for each group) among 6 can be set on the beam using an horizontal translation, thus resulting in 16 configurations (including direct beam pass) suitable for various experiment needs and energy range. Each group can be separately removed and features a 3 axis motorized alignment system (z, Θx, Θz)
• Water cooling of lenses (absorbed power =10W on the 1st lens)
• Operating in UHV.
• 6 lens blocks removable independently.
• X axis translation for lens block switching and fine positioning:
  ✓ Stroke=150 mm  repeatability = 0.5 µm
• Alignment setting on each lens block:
  ✓ Z translation= ±1 mm resolution = 0.1 µm.
  ✓ Θx et Θz rotation= ±0.5° resolution = 50 µrad
• Low thermal drift and sensitivity to vibration.
• Positions are kept in case of power loss.
• Width limited by the neighborhood of the second beamline.
Each lens block must be removable individually and cooled to drain a maximum power of 17 W, under vacuum.

Direct cooling by water circulation in the lens holder → **great efficiency**, but...

- use of tubing with many connections under vacuum → great leak risk.
- direct water circulation → vibration risk.
- tubing used on a large stroke → strain on mechanics.

Use of copper braids between lens holders and a fix cooled block → **good vibration insulation, low strain, easy disconnection**, but...

- long stroke implies long braids → low thermal draining efficiency.

Use of copper braids between lens holders and a “following” cooled block → **good vibration insulation, no strain, easy disconnection**, but...

- short braids → better efficiency, but anyway less than direct cooling.
- synchronization of cooler block and lenses needed on all the stroke.
- more complex → more expensive.
Lenses are stacked in a copper shell, the thermal contact resistance is reduced via a silver coating on the cylindrical contact surface. The lens holder is insulated from the setting mechanics by alumina columns to limit thermal drift. Heat is transferred to a common water-cooled block using 4 copper braids.
LENSES MODULE (3 BLOCKS)

- Bellow
- Copper braids
- Cooled block translator on air side
- Cooled block
- X-ray beam direction
- X translation piezo motors (tandem configuration)
THERMAL ANALYSIS

4 braids (actual section= 10mm² each)
Heat transfer coefficient=0.02W/(mm²･K) at all interfaces

→ 115 °C at hottest position

<table>
<thead>
<tr>
<th>Lens</th>
<th>Absorbed power (W)</th>
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<tbody>
<tr>
<td>1</td>
<td>10</td>
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<tr>
<td>2</td>
<td>2.7</td>
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<tr>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td>4</td>
<td>1.2</td>
</tr>
<tr>
<td>5</td>
<td>0.9</td>
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Drift along Z=25µm at optical axis

Can we avoid this drift by changing the design?
Insulating columns are fixed in the beam plane. **Thermal expansion of copper block has no influence on Z position.** Resulting Z drift is 4µm at optical axis.
OVERVIEW OF A LENS POSITIONNER

- Beam axis
- Rz flexor
- Rx flexor
- Tz flexor
- Tz rotative piezo motor
- Tz capacitive sensor
- Rz DC motor
- Rx DC motor
- Rocker lever
Additional arms improves vertical and torsional stiffness
Stroke = 0.5°
Resulting stresses for 0.5° stroke
Material: titanium alloy (Ta6V)
Rx and Tz FLEXURAL PIVOT ANALYSIS

Double parallelogram design improves lateral and torsional stiffness
Resulting stresses for 1mm stroke
Material: titanium alloy (Ta6V)
Resulting stresses for 0.5° stroke
Rx and Tz FLEXURAL PIVOT ANALYSIS

A: Structure statique
Déplacement total
Type: Déplacement total
Unité: mm
Temps: 1
29/11/2013 12:11

Evaluation of lateral stiffness

$F=10 \text{ N}$
1st MODE= 462.8 Hz
2nd MODE = 506.3 Hz
3rd MODE = 552.5 Hz
4th MODE = 801.7 Hz
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THANK YOU FOR YOUR ATTENTION

See also poster presentation on XRM:
*The ANATOMIX Beamline Project at Synchrotron SOLEIL*,
T. Weitkamp et al., abstract no. 345

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