CASTOR: a new goniometer for grazing incidence X-Ray analysis at the SOLEIL synchrotron

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Thin films made of stacked multi-material layers have an increasing importance for high-technology industrial developments, for example, solar cells using HfO_2 or transparent conductive oxide made of ZnO. The performance of these materials is closely related to the quality of the interfaces between the different layers, the roughness and the homogeneity. So thorough studies of these properties must be carried out in order to obtain efficient devices. **Grazing incidence X-ray fluorescence techniques are of major interest as they can give information about in-depth and interface properties of micro and nano-structured materials.**

CASTOR: a new tool for metrology at SOLEIL

CASTOR (Chamber for Analysis and Spectrometry in Transmission Or Reflection) is based on prototypes from Physikalisch-Technische Bundesanstalt (PTB) and Technical University Berlin.

It is composed of:
• A high vacuum chamber,
• A 7-axis manipulator (three rotations and four translations),
• A movable frame to operate on different beam lines.
Different detectors such as a Silicon Drift Detector (SDD) or a calibrated photodiode can be used.
Multiple analysis techniques will be used such as GIXRF, XRF, XRR,TXRF, etc.
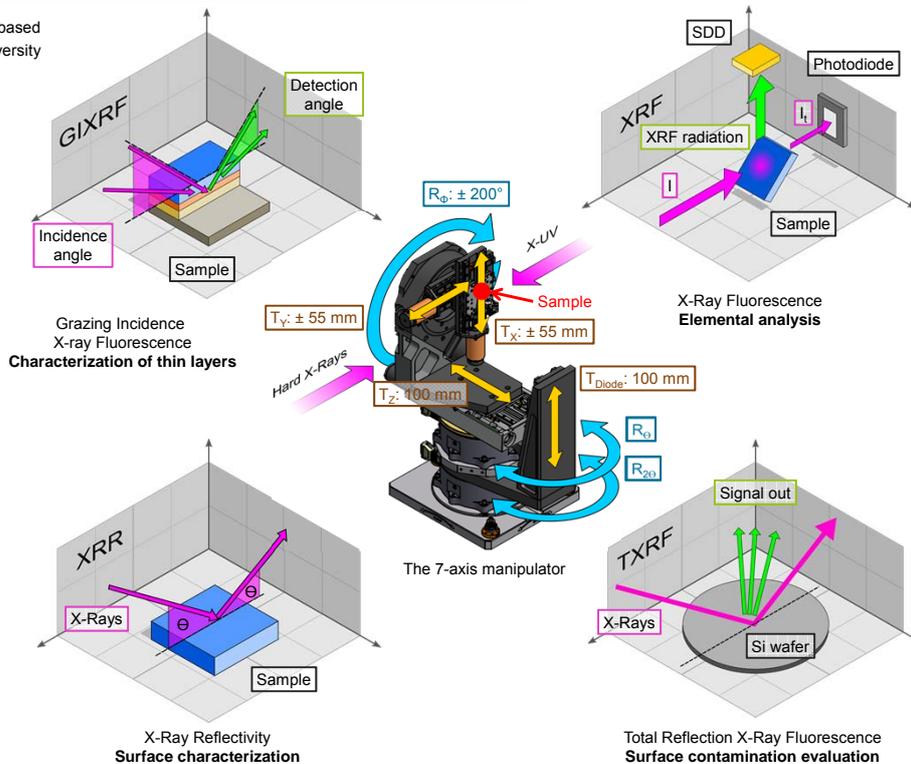
The CASTOR setup (right) and its control and readout electronics (left).

CASTOR operates on the SOLEIL Metrology beamline.
• From 30 eV to 1.8 keV → "X-UV",
• From 3 keV to 35 keV → "Hard X-Rays".

GIXRF
Detection angle
Incidence angle
Sample

Grazing Incidence X-ray Fluorescence
Characterization of thin layers

R_Φ: ± 200°
X-UV
Sample
T_Y: ± 55 mm
T_X: ± 55 mm
T_Z: 100 mm
Hard X-Rays
T_{Diode}: 100 mm
R_Θ
$R_{2\Theta}$

The 7-axis manipulator

SDD
Photodiode
XRF
XRF radiation
I_t
I
Sample

X-Ray Fluorescence
Elemental analysis

XRR
X-Rays
Θ Θ
Sample

X-Ray Reflectivity
Surface characterization

TXRF
Signal out
X-Rays
Si wafer

Total Reflection X-Ray Fluorescence
Surface contamination evaluation

Data acquisition

The driving and data acquisition software has been developed with National Instruments LabVIEW®.

Several tasks must be handled in parallel
• Pumping,
• 7-axis manipulator motors,
• Monochromator for energy selection,
• Data acquisition,
• Multiple detectors,
• 2 motors for the frame.

→ **Solution**: **Finite-State Machines (FSM) one FSM per independent task.**

SOLEIL uses TANGO, a free open source device-oriented controls toolkit for controlling hardware like synchrotrons, lasers, etc.

Sending commands to CASTOR requires several steps as shown on the controlling scheme:
1. A command is generated by the user on the software interface,
2. The command is sent to the related FSM,
3. The FSM sends a command to the corresponding TANGO device using abView/TANGO bindings,
4. TANGO sends the command to the apparatus.

Retrieving information from the beamline uses the reverse order.
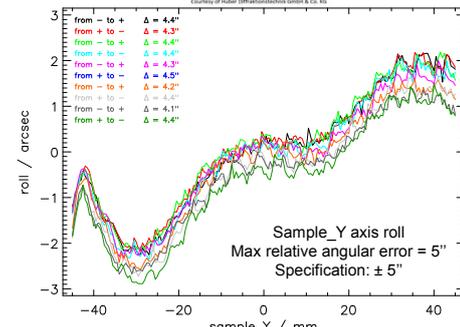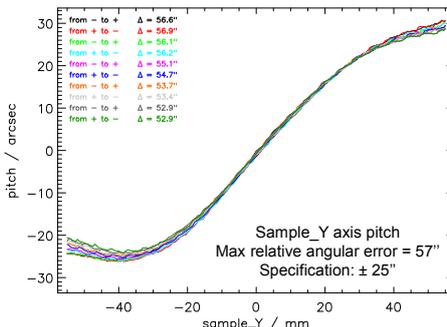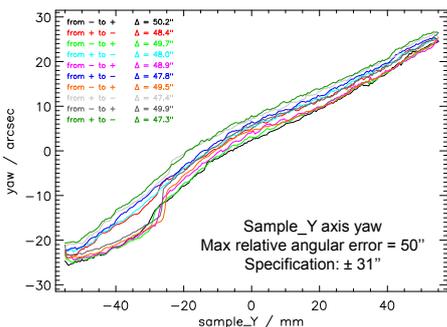

CASTOR controlling scheme
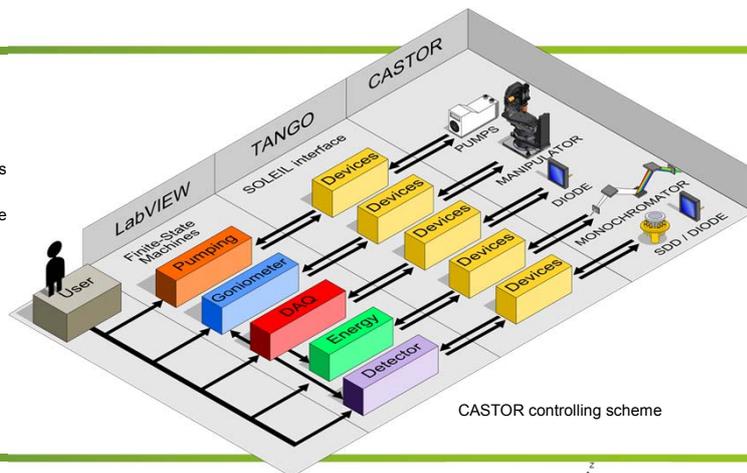
Commissioning

High accuracy XRS and XRR measurements require a very good characterization of the 7-axis manipulator
→ each axis has been thoroughly studied.
The analysis has been carried out at PTB with an autocollimator (3000 ELCOMAT by Möller-Wedel optical GmbH) and a mirror mounted on the manipulator.
Results of the Sample_Y axis are shown in the figures below.

pitch yaw roll

Sample_Y axis yaw
Max relative angular error = 50''
Specification: ± 31''

Sample_Y axis pitch
Max relative angular error = 57''
Specification: ± 25''

Sample_Y axis roll
Max relative angular error = 5''
Specification: ± 5''

Both pitch and roll are better than the specifications. Yaw is slightly out of the specifications, but still acceptable.