Development of Instrumentation for X-Ray Spectroscopy at P64

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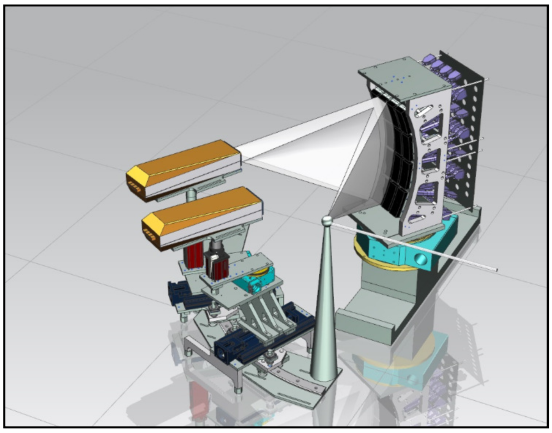
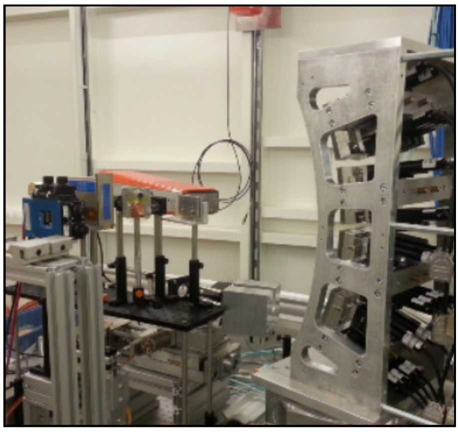
Von Hamos Spectrometer

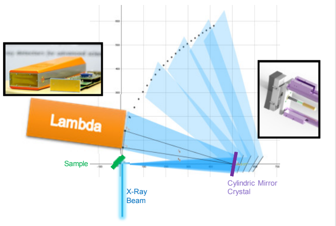




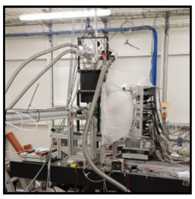
Set-Up

Last year, in 2017, a new Von Hamos-type X-ray emission spectrometer was constructed and build at the beamline P64.
The spectrometer consists of:

- a sample environment system, which works in a 90° fluorescence mode
- an 4x4 cyllindrical curved mirror array, with each crystal being cylindrically curved with a radius of curvature 500 mm
- two Lamda detectors in order to observe the fluorescence of different elements at he same time

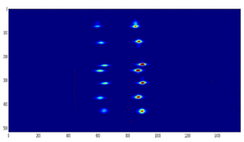


The picture above shows the basic geometry of the beam.
Cylindric bragg crystals will reflect the fluerencent X-rays and produce a spectral line which will be measured with the lambda-dector – a 2D x-ray detector.
The sketch also shows side crystals (light red shape) which can be aligned to the same detector like the central crystals.



Spectrometer in use with our He-Cryostat

First Measured spectra Cu-fluorescence at K-Edges



Construction of an optimal fitted rail for the detector positioning

Motivation

In order to have as less adjustment work as possible, a rail was constructed to position the detector. The needed curvature can be approximated by the combination of two rails with different radii.

Solution

While working constantly with a 500 mm curved cylindric array the detector-position can be described as a steady function.

$$y = \sqrt{0.5 \cdot \sqrt{(16 \cdot l^2 \cdot x^2 + x^4)} - 0.5 \cdot x^2}$$

The sample will be positioned at the point (0,0) and „l" is the curvage-radius of the Crystals.
The formular can found by reducing some basic geometry equations. (see picture: isosceles triangle with constant high of *l=500*)

The aim was to find a cost efficient solution with rails in the sense, that two curved rails fixed together should achieve a good description of the detector position.
The curvature of the two rails can be described as:

$$y = \begin{cases} \sqrt{r_1^2 - ((x - x_{m1})^2)} + y_{m1} & x \le x_{r12} \\ \sqrt{(r_2^2) - (x - x_{m2}(x_{m1}, x_{r12}, r_1, r_2))^2)} + y_{m2}(y_{m1}, x_{r12}, r_1, r_2) & \text{other} \end{cases}$$

$$\left| \begin{array}{ll} (x_{m1}, y_{m1}): & \text{mid point of the first rail} \\ (x_{m2}, y_{m2}): & \text{mid point of the second rail} \\ (x_{r12}, y_{r12}): & \text{touching point of both rails} \end{array} \right.$$

To find the optimal radius and curvature of the rails a simple Levenberg-Marquard curve fitting can be used. Therefore it is sufficient to describe the equations in polarcoordinates at the point *(500,0)*

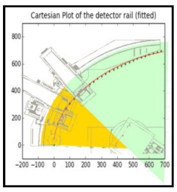
$$r_{detect} = \sqrt{(x - 500)^2 + (y^2)}$$

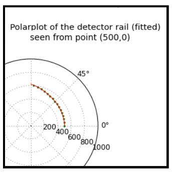
The fitting problem can be described by the reduction of the sum of residuums by the following formular:

$$\min_p \| r_{detect} - r_{curve}(p) \|_2^2$$

$$p = < x_{m1}, y_{m1}, r_1, r_2, x_{r12} >$$

The result of the fitting can be seen in the follwing figures:





The rails were manufactured and positioned according to the radius and positions, which one got out of the fitting results.

Positioning stage for cylindrical crystals [with a suppression of tilt effects]

Motivation and Requirements

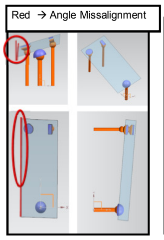
When the sample is hit by the x-ray beam, the produced fluorescent rays will be reflected by the cylindrical Bragg crystals and produce a spectral line on the detector. Therefore it is effective that independandant of the position of the motor stage the reflection always results in a parallel horizontal spectral line.
In order to achieve that some modifactions have to be made onto the standard positioning concept.

Solution

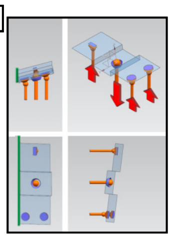
The positioning unit consists of three linear motors. A ball joint is connected to a back-force spring. Two linear motors are connected to a plane joint and one to a linear joint.
The positioning unit was constructed in that way, that the reflected spectral lines always stay parallel. Therefore the ball joint and the linear joint have to lie on the same base line, so that the resulting coordinate system for the crystal holder is set in such a way that the y-Vector (see picture) always stays in a plane parallel to the the cylindric central line of the cylinder (from the crystal shape). This will always result in parallel spectral lines on the detector, independent of the alignment of the linearmotors.

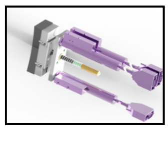
BASIC Positioning concept:

Red → Angle Missalignment



NEW modified concept: with less Tilt Effects





Liquid Sample Cell

Motivation and Requirements

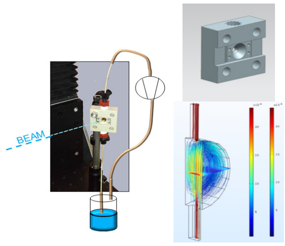
Cause of several requests of users, a liquid sample cell was constructed.
The following requirements were discussed:

- No leakage/ No loss of sample
- Working in Absorption and Fluorescence mode
- Material: free of metal
- Adaptable to vacuum-tubes
- Measurement of small amounts of liquid

One additional important point is, that during x-ray operation it could appear that free radicals were produced which will result in bubbles.
These bubbles distort the measurement and should be prevented.

Liquid Sample Cell - First Prototype

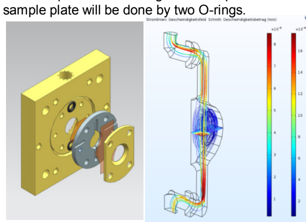
The sketches in the left corner below show the first prototype.
The cell has a inlet at the bottom of D=1.2 mm and an outlet at the top of D=0.8 mm. The pump will be connected at the top in order to create no overpressure in the cell.
In case of appearing bubbles the pump is able to suck them away.
The cell consists of one base body (PEEK) and two cover plates (PEEK) which will be connected on both sides. Inbetween base body and plate a captonfoil and a Viton-foil will be placed. Parts are hold and pressed together by four M2 screws.



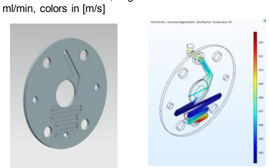
Liquid Sample Cell V1.0: Left: CAD Construction; Right: CFD simulation with a flow of 0,3 ml/min colors in [m/s]

Liquid Sample Cell – Second Version

After the first prototype some modifications were considered. The new sample cell can be connected to standard ISO KF40 flanges for in vacuum operation. It consists of one base plate (PEEK) one liquid-sample-Plate and a counter plate.
The advantage in comparision to the first version is, that depending on the requirements the sample plate is changleable and can be modified (p.e. in thickness or flow distribution).
For first measurements a sample aluminium plate with glued capton windows will be screwed on the base plate. The sealing from baseplate to sample plate will be done by two O-rings.



Left: CAD Construction; Right: CFD simulation with a flow of 0,3 ml/min, colors in [m/s]



Left: CAD Construction: concept of a sample plate with additional heating cooling path; Right: CFD simulation with a flow of 0,3 ml/min, colors: Temperature in [K]