Design of a flexible RIXS Setup.

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Abstract

We present a new mechanical design for a RIXS experiment setup consisting of a sample environment vacuum chamber and corresponding spectrometer. It allows variable beam incidence angles to the sample as well as observation angles of the spectrometer.

The dispersive element of the spectrometer can be aligned in five DOF by motors inside the UHV chamber. The alignment of the CCD detector can be adjusted independently in the lateral and longitudinal position as well as incidence angle. In combination with a tiltable detector chamber this design allows for multiple observation methods, not limited to variable energies but also for use of different optics or direct observations of the sample.

Introduction

The experiment examines samples by the RIXS mechanism. X-ray photons excite an electron in the sample to a higher state of energy by absorption of the photon. When the electron falls back on the core level a RIXS photon is emitted under a different angle, momentum and energy. These photons and their interference pattern are measured by the detector.

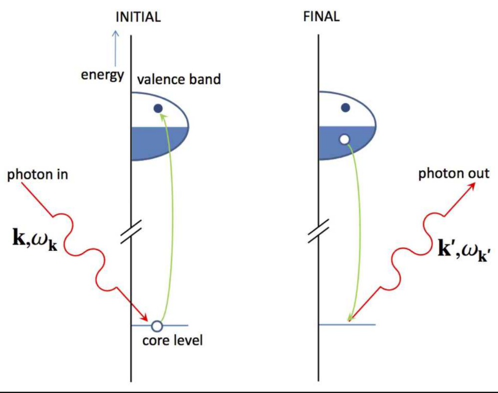

Figure 1: Physics of the RIXS Mechanism. [1]

Requirements

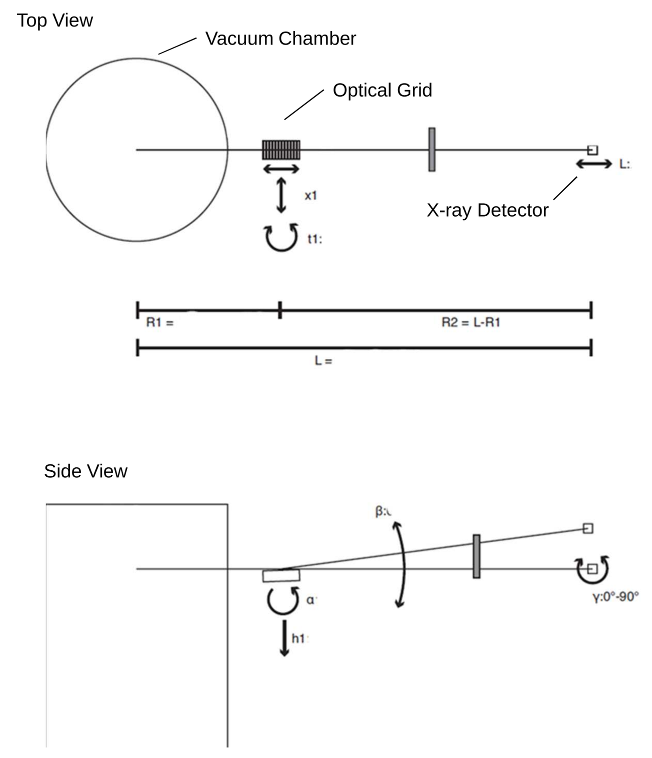

Figure 2: Position and movement paramters for optical elements. [2]

Requirements for the setup are according to Fig. 2 and 5, as well as Table 1. In Addition the entire spectrometer Setup must rotate around the Sample Chamber.

The setup need not support changing the entire scattering angle field without breaking vacuum. Rather a cost effective yet easy to use and quickly changeable support structure has to be chosen.

The Design of the Sample Chamber is fixed from the beginning of the design phase which also restricts placement of mechanics and supporting infrastructure. [2]

Experiment Setup – Overview

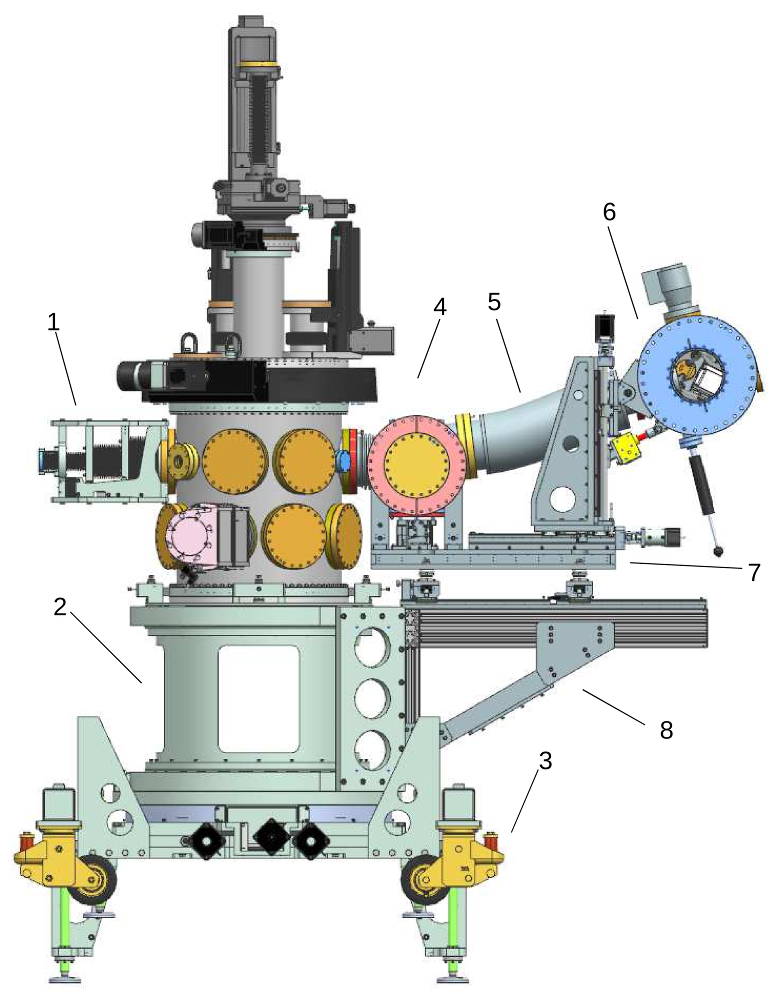

Figure 3: Overview of the experiment. Motor driven bellow system (1), Support structure (2), Gear system (3), Grid Chamber (4), DN150 Bellow (5), Detector Chamber (6), Spectrometer alignment table (7), rotating spectrometer support structure (8).

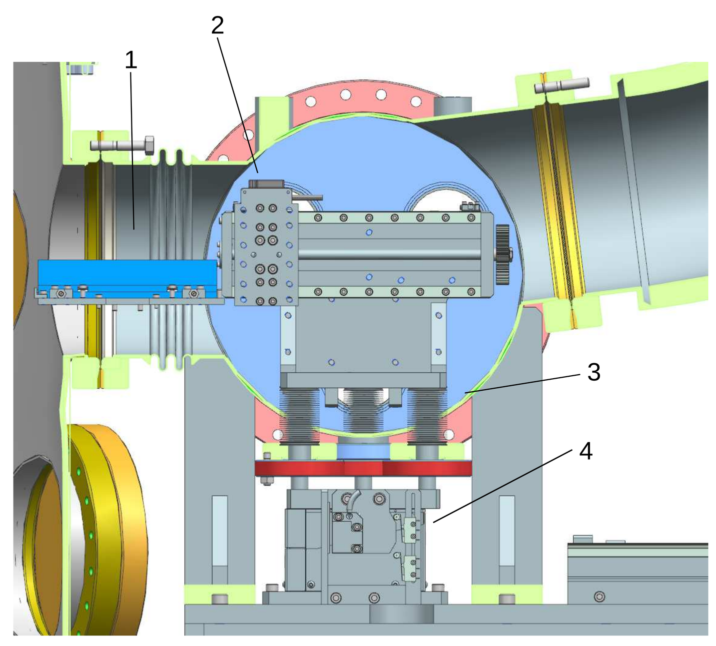

Figure 4: Cross section detail view of the Grid Chamber. Grid holder – easily changeable (1), Grid stage x axis – Parameter R1 Table 1 (2), Grid z axis feedthrough (3), Grid z axis actuator – lower the grid to allow direct incidence from sample to detector (4).

Axes and Ranges of Movement

To observe RIXS photons at the energy spectrum from 50eV to 650eV the positions of grid and detector have to be changed. The optical parameters are optimized to space constraints (available area at end station as well as placement of objects and assmbly space required) and imaging qualities on the detector.

In addition to the ranges of movement of grid and detector according to Fig. 5 and Tab. 1 the setup can move the detector to any position in the rectangle defined by the two extreme points. Also a direct view from sample to detector is possible as well as observation of the sample (See Fig. 6 Pos. 9).

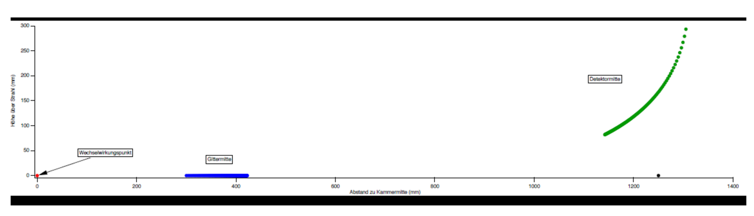

Figure 5: Position of source point, optical grid and center of detector. Refer to Table 1. [2]

Energy eV	R1 mm	L mm	alpha deg	beta deg	gamma deg
50	300	1347	87,9	75,8	53,54
200	364	1240	87,9	82,7	23,11
400	399	1183	87,9	84,6	17,4
650	422	1146	87,9	85,6	13,9

Table 1: Correlation of RIXS photon energy and positions of optical elements. Refer to Fig. 2 and 5. [2]

Spectrometer Design

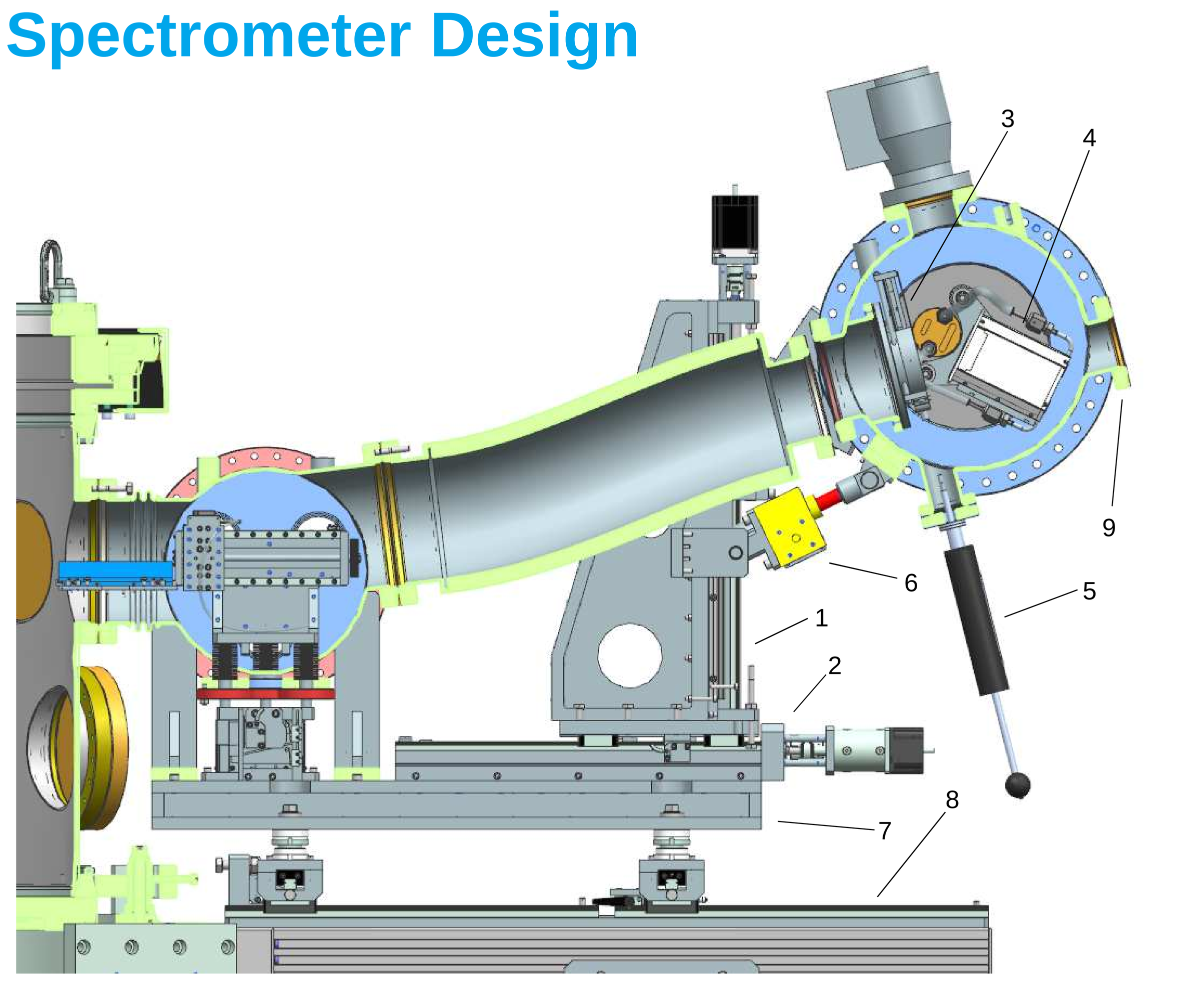

Figure 6: Cross section view of the Spectrometer. 1: Detector chamber z lift support and actuator, stepper motor with trapezoidal threaded shaft, two parrallel linear guides; 2: Detector chamber x actuator and support, actuator same as for z lift; 3: Filter/Shutter Unit, see below Figs. 11, 12; 4: Detector, mounted on rotating feedthrough on the backside flange of detector chamber, electrical and cooling feedthrough; 5: manual linear feedthrough to operate Filter/Shutter unit Pos. 3; 6: Detector chamber tilt actuator. Allows to optimize the inlet aperture to be optimized and also to provide direct view to sample through flange 9; 7: Spectrometer support structure. Adjusts Detector Chamber to Sample chamber and slides back on rails of rotating support Pos. 8 when changing flanges; 8: Rotating support structure. Fixed on Sample Chamber Support Structure, rotates 360°; 9: Observation port with DN63 window flange.

The vacuum layout of the spectrometer consists of a grid chamber (DN250) that is connected to the sample chamber, and a detector chamber (DN300) connected to the grid chamber via a DN150 edge welded bellow. Figure 6 shows the setup in a side view. The grid chamber is fixed on a alignment table that sits ontop of the rotating spectrometer support structure. It is used to perfectly align the spectrometer inlet flange with one of the sample chamber flanges. In addition it allows the spectrometer to be moved away from and clear the sample chamber during rotation to another sample chamber flange.

The detector chamber is supported in a three axis motor driven frame which sits ontop of the alignment table. This frame can move the chamber in the x and z direction and also tilt the chamber so that its inlet flange always points in the direction of the sample.

Positioning Unit - Requirements

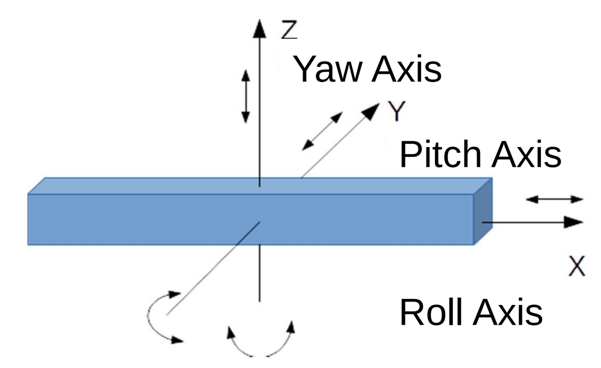

Figure 7: Axis system for grid positioning unit.

To align the optical grid according to the requirements and under the spacial restricions (the grid is located directly in the chamber port and bellow) a positioning unit was developed. The movement and resolution requirements are according to Table 2. The design is optimized for weight, range and accuracy of motion as well as vibration stability.

The design is currently pending for patent application and no further details may be presented at this time.

Axis	Requirement	Reference Implementation	Resolution per step
x	+/- 100 mm	+/- 122 mm	
y	+/- 2 mm	+/- 6 mm	
z	0 – 12 mm	0 – 12 mm	
rot y	1° – 3°	-1° – 4.5°	0.6 µrad
rot z	+/- 3°	+/- 3.5°	

Table 2: Requirements for Positioning Unit and achieved frame of motion in the reference implementation.

Support Structure

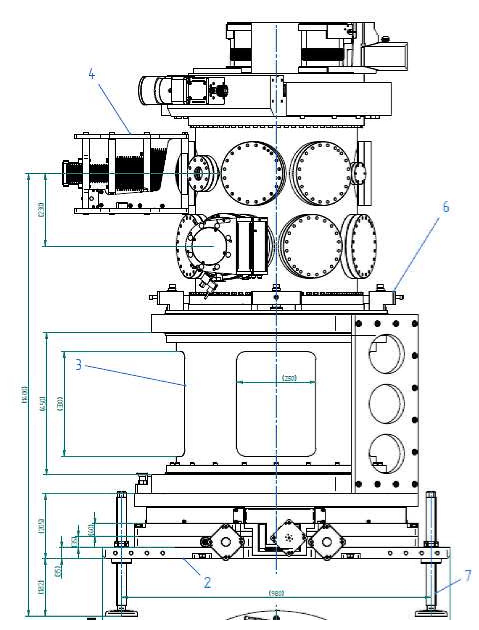

Figure 8: Support structure of the sample chamber [3]

The chamber is mounted on a support structure that can be adjusted to multiple beam heights above the floor and has foldable wheels for easy transport of the entire setup. The lower alignment system of the setup has motor driven x, y and rot z stages for fine tuning of the position [3]

To allow for variable observation angles with the spectrometer the support structure features a DN500 diameter rotational bearing that connects the spectrometer support to the chamber support. This rotational support can be locked in positions perfectly aligned with the flanges of the chamber. [3]

Sample Environment

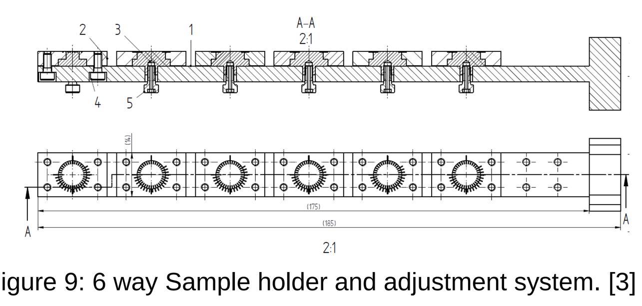

Figure 9: 6 way Sample holder and adjustment system. [3]

The sample is located in a vertical, cylindrical vacuum chamber and is inserted from the top. The top flange of the chamber is a rotating feedthrough which supports the sample holder and additional infrastructure. The sample can be cooled to 25K or heated to about 350K. [3, 5]

To vary the angles between beam incidence on the sample and observation angle of the spectrometer a cost-effective solution was chosen. The beamline is connected to the chamber by a motor driven bellow system that can support incidence angles of +/-15°. For larger changes of incidence angles however the vacuum connection has to be broken and the bellow system has to be attached to another flange. By using all ports on the sample chamber any scattering angle can be reached. [3, 5]

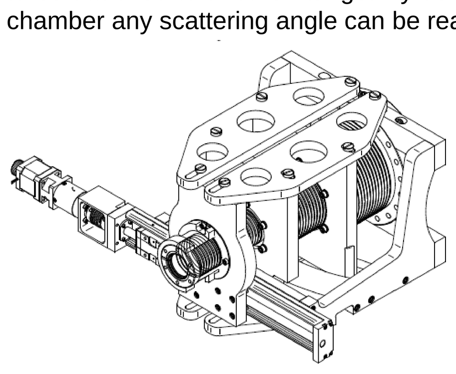

Figure 10: Motor driven bellow system to connect the Beamline to the sample chamber. [3]

Filter/Shutter Unit

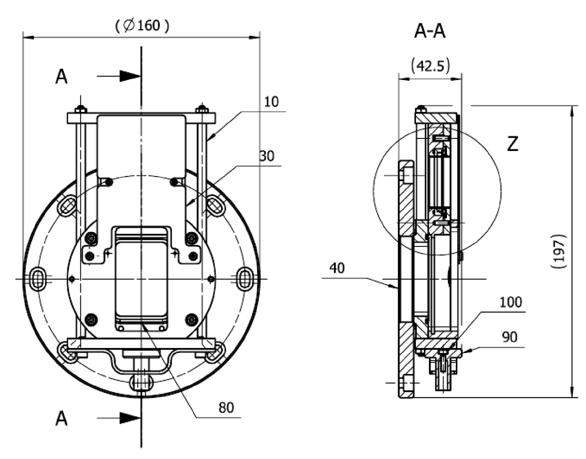

Figure 11: Manufacturing drawings of Filter/Shutter unit [4]

Behind the inlet flange of the detector chamber an in-vacuum filter unit is placed which can either block light from entering the detector chamber if the filter is in place or provide a rectangular open aperture of 50 by 35mm. The filter unit is designed to be completely light tight when closed. To achive that a combination of labyrinth seal, axial O-ring seal and a spring loaded tight fit of the surfaces is used. The filter unit is operated by hand from outside the vacuum by a linear feedthrough. The filter types can be easily changed during maintenance. [4]

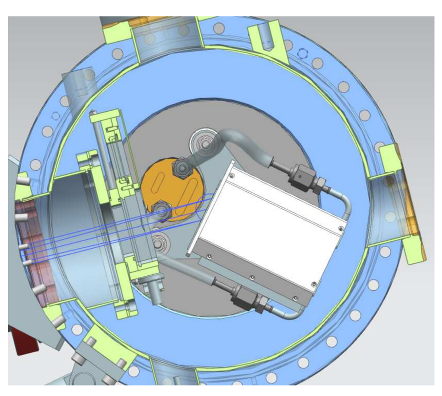

Figure 12: Shutter Unit in open position as installed in the detector chamber. [4]

Conclusion and Outlook

Design, manufacturing and assembly of this first stage is complete and the first measurements are ongoing. Even with not all motorized axes yet available the alignment and handling of the setup is very easy. Also the alignment, handling and stability of the dispersive element and the detector is well within the specified parameters for precision.

The design of the positioning unit for the dispersive element is currently patent pending.

A planned upgrade of the setup will rotate the spectrometer by 90° so that the detector moves in the horizontal plane.

Figure 13: MUSIX Setup as installed at FLASH II Beamline 24 in May 2018. [6]

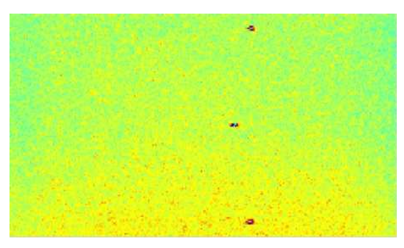

Figure 14: Detector image during commissioning in May 2018. [6]

References

[1] Wikimedia Commons contributors, "File:Direct RIXS process.jpg," *Wikimedia Commons, the free media repository,* https://commons.wikimedia.org/w/index.php?title=File:Direct_RIXS_process.jpg&oldid=223804406 (accessed June 22, 2018).
[2] MUSIX Spectrometer Specification by Dr. Martin Beye.
[3] Design by Dipl-Ing. Ernst-Otto Saemann.
[4] Concept and Design by Torben Reuss.
[5] FLASH Newsletter 03/2018.
[6] Images by Dr. Martin Beye.

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