ISBN: 978-3-95450-229-5 ISSN: 2673-5520 doi:10.18429/JACoW-MEDSI2020-WEPC04

A COMPACT X-RAY EMISSION (mini-XES) SPECTROMETER AT CLS - DESIGN AND FABRICATION METHODS

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Abstract

A compact X-ray emission spectrometer (mini-XES) has been designed and fabricated for use at the Brockhouse undulator beamline. The mini-XES design was developed to be as simple to fabricate and as easy to operate as possible. We tried to minimize the number of parts. From the beginning, the design was trying to achieve no tools assembly, alignment, and operation. The first tests of the spectrometer were completed and were successful.

INTRODUCTION

A compact X-ray emission spectrometer (mini-XES) has been designed and fabricated for use at the Brockhouse undulator beamline [1]. The mini-XES uses cylindrical von Hamos geometry tuned for Fe K-edge and uses a Pilatus 100K area detector from Dectris [2]. It is based on a general design implemented at the APS [3].

The mini-XES design was developed to be as simple to fabricate and as easy to operate as possible. We tried to minimize the number of components, so there are only two main parts that create a chamber. Those two components are joined and aligned by a NW-80 flange. From the start, the design was trying to achieve no tools assembly, alignment, and operation. For lower precision alignment we decided to use the centering ring of the NW-80 flange which, together with two posts integrated with the chamber, provides an adequate method for joining the two parts of the enclosure. We use level vials for horizontal adjustment of the holder for the 10 crystals. For high precision alignment of the crystal holder, we use the Thorlab KC1/M kinematic mount, which have the adjustment screws accessible from outside of the chamber. The fabrication was done in-house using uPrint SE Plus 3D Printer [4].

The first tests of the spectrometer were completed in the Brockhouse wiggler beamline [5] and were successful. Future improvements will aim to reduce the background scatter and better position the detector, to improve the fill. Now that the relatively inexpensive design was tested and tried, there is an option to upgrade it to 3D printed tungsten or steel version that would intrinsically provide the required shielding.

MAIN COMPONENTS

The spectrometer consists of:

- Top Chamber
- Bottom Chamber
- Crystal Holder with crystals
- Apertures

The estimates for the model material used and the print time are included in Table 1.

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Main Printed Components

The top chamber (Fig. 1), attaches to the detector and the design protects the sensitive part of the detector. It assures that there is no possibility of contact with the focal plane once the detector is ready to use. The other end of the chamber mates to the NW-80 flange.

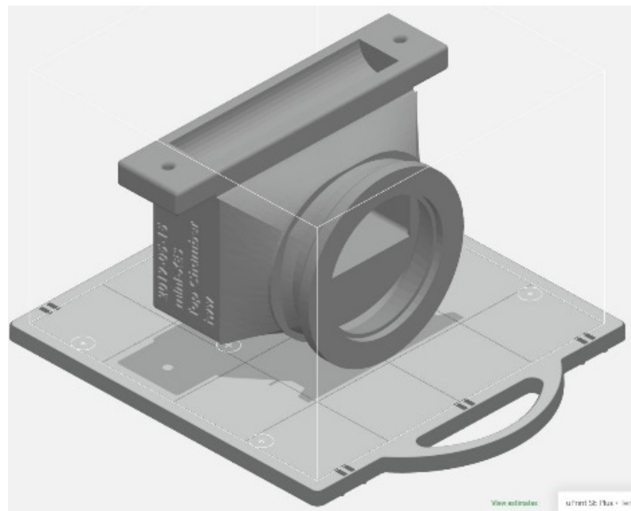

Figure 1: Top chamber model.

The bottom chamber is more complex (Fig. 2). It starts with NW-80 flange at the top that connects to the top chamber. The centering ring provides axial alignment. Two horizontal arms, that contact the backplate, provide the rotational alignment.

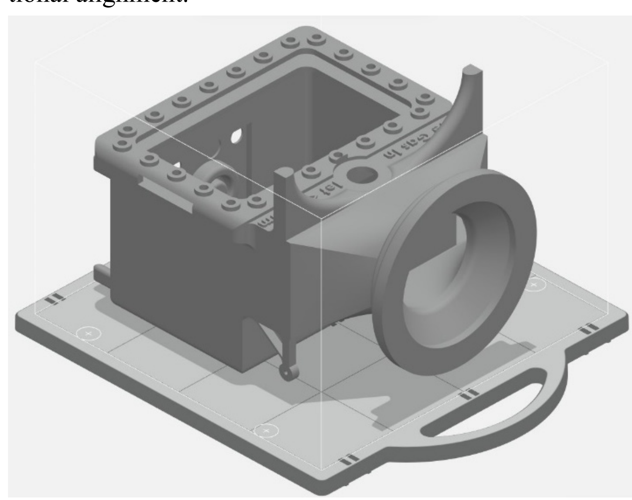

Figure 2: Bottom chamber model.

The chamber has several slots for apertures, a slot for the back door, support legs and alignment posts which combined with the alignment lines help to position the sample at the right location.

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As can be seen, the parts were very close to the maximum part size that the uPrint SE Plus 3D printer could fabricate: 203x203x152 mm^3 (8x8x6 in^3).

Table 1: Model Material and Print Time Estimates

Part name	Model Material [cm^3/in^3]	Print Time [hours]
Top Chamber	226/13.8	24
Bottom Chamber	389/23.7	42
Crystal Holder	46.2/2.8	5
TOTAL	661.2/40.3	71

Additional Parts

For alignment between the top and bottom chambers, we decided to use the centering ring of the NW-80 flange which, together with two horizontal posts integrated with the bottom chamber provide an adequate method for joining the two parts of the enclosure. NW-80 flange was chosen as it provides the minimum window opening required for the design. We use three level vials for initial horizontal adjustment of the crystal holder (Fig. 3).

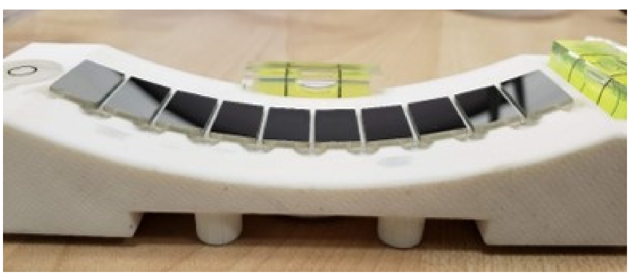

Figure 3: A photograph of the crystal holder with Ge (620) crystals installed with small dabs of Apiezon M vacuum grease. At the bottom, press-fit posts are visible, which are used to attach the holder firmly to the kinematic top plate.

For higher precision alignment of the crystal holder, we use the Thorlabs KC1/M kinematic mount (Fig. 4). We use a press-fit geometry to anchor the rear plate to the floor of the bottom chamber from inside and to anchor the front plate to the crystal holder. The adjustment screws are accessible from outside of the chamber and the legs on the bottom chamber protect them from contacting any surface.

The back door was made out of Lucite (PMMA) plate (0.25” thick). The door has an O-ring installed into the machined grove and it is pressed against the chamber wall using M-6 Thumbscrews from Thorlabs (TS6H/M-p5).

The chamber has threaded holes that provide enough accuracy for the thumbscrews to work. As a redundancy, in case of thread failure, 24 threaded holes are provided. A backup option would be to install metal inserts into failed plastic threads if needed.

We also integrated a quick disconnect port for the He supply line above the door (Fig. 4). There is no exhaust port as the flow out is provided by diffusion thru the walls, and by small openings in the chamber around the kinematic mount adjustors and back door.

Figure 5 shows a closeup of the bottom chamber. The crystal holder and its alignment system are visible thru the Lucite back door. Several of the thumbscrews pressing the back door to the chamber are visible.

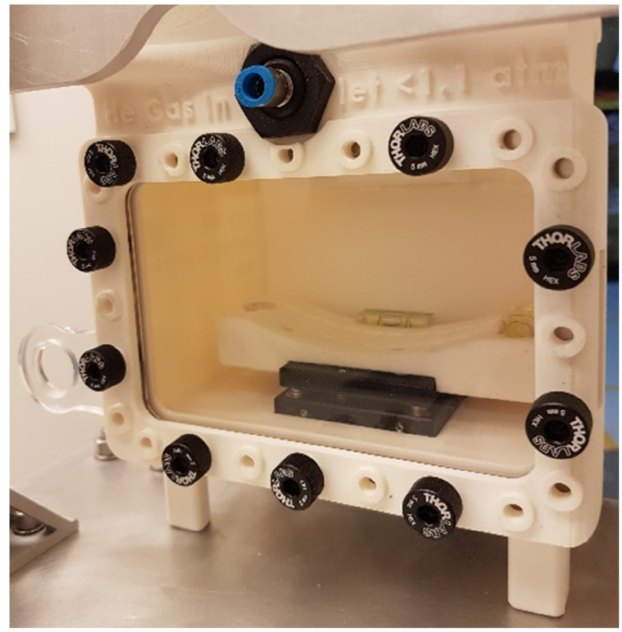

Figure 4: Close-up of the bottom chamber with crystal holder, back door, and He supply port.

Figure 5 shows the same bottom chamber from the user access side. Alignment posts help to align the complete assembly with the beam and the sample. Aperture holders are designed to easily slide in/out from the chamber housing.

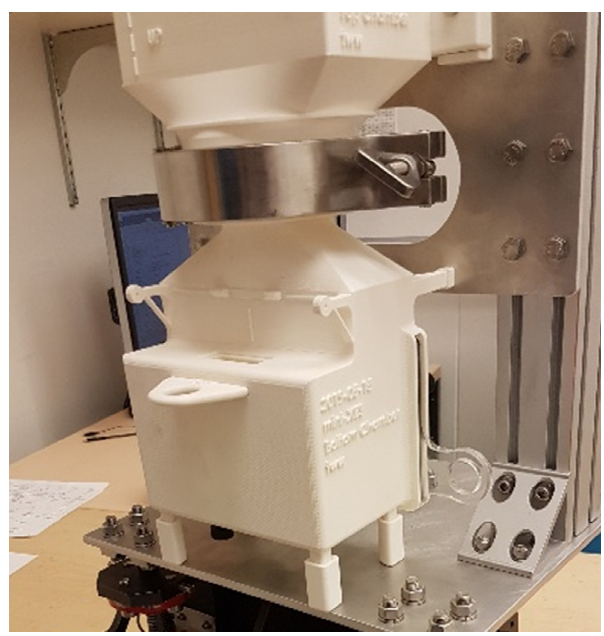

Figure 5: User side view of the completed assembly attached to the positioning table.

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Sealing the Chamber

We applied several coats of Woods™ Waterproof Silicone Spray to seal the plastic walls as much as possible. We used a Kapton window to close the top of the chamber, next to the area detector. The top chamber design has an internal horizontal flat with a window cut-out for that purpose.

COMPLETED ASSEMBLY

The mini-XES is attached to an external aluminium plate and frame structure that provides required support and has additional motorized jacks for alignment (Fig. 6). Additional shielding was added to minimise external scatter and to improve S/N ratio.

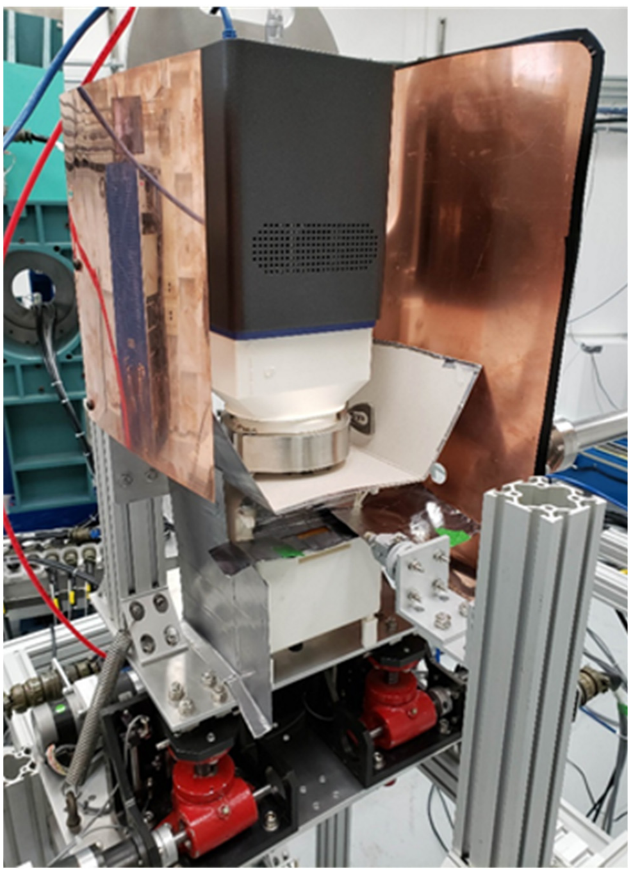

Figure 6: A photograph of the experimental setup with outside shielding in place.

FIRST TESTS

The device works! (Fig. 7). Our observations compare well against the APS paper [3]. The jacks work well with good motion, but they must be spaced out further to provide more stability. Positioning of the sample is manual, tedious, and time-consuming. A 3-axis motorized sample positioning system is required.

To better fill the detector, the top chamber should be optimized by a few mm. It would be helpful if the detector had some vertical adjustment.

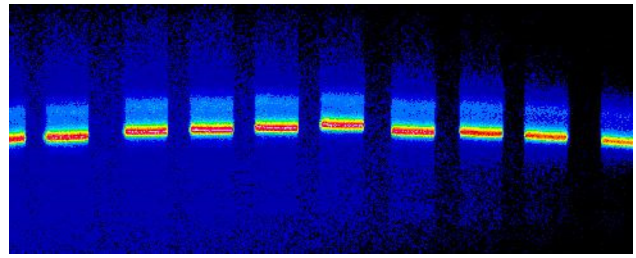

Figure 7: Recorded fluorescence of the Fe_2O_3 nanoparticles, 20-50 nm diameter.

CONCLUSION

A compact X-ray emission spectrometer (mini-XES) has been designed and fabricated for use at the Brockhouse undulator beamline. The mini-XES uses cylindrical von Hamos geometry tuned for Fe K-edge and uses a Pilatus 100K area detector from Dectris.

The mini-XES design was developed to be as simple to fabricate and as easy to operate as possible. We tried to minimize the number of components so there are only two main parts that create a chamber, which are joined by NW-80 flange. The design was trying to achieve no tools assembly, alignment, and operation.

The first tests of the spectrometer were completed and were successful. Future improvements will aim to reduce the background scatter and to provide better positioning of the detector, to improve the focal plane fill.

Now, that the relatively inexpensive design was fabricated, tested, and tried, there is an option to upgrade to 3D printed tungsten or steel version that would intrinsically provide the required shielding. Likewise, the Lucite back door could be replaced with lead glass or lead acrylic material to further reduce the scatter.

ACKNOWLEDGEMENTS

Part or all of the research described in this paper was performed at the Canadian Light Source, which is supported by the Canada Foundation for Innovation (CFI) and others agencies.

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