MEDSI CHICAGO 2020

A Compact X-ray Emission (mini-Xes) Spectrometer at CLS - Design and Fabrication Methods

Tomasz W. Wysokinski, Morgan Button, Adam F. G. Leontowich, Beatriz Diaz Moreno

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 holder of the crystal, we used the Thorlab KC1/M kinematic mount, which had 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 back-ground 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.

3D PRINTING

The spectrometer consists of: Top Chamber (Fig.1), Bottom Chamber (Fig.2), Crystal Holder with crystals (Fig.3) and Apertures.

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

The top chamber attaches to the detector. The bottom chamber starts with NW-80 flange that connects to the top chamber. The centering ring provides axial alignment. Two horizontal arms, that contact the backplate, provide the rotational alignment. The chamber has several slots for apertures, a slot for the back door, and support legs.

Table 1. 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


Fig. 1

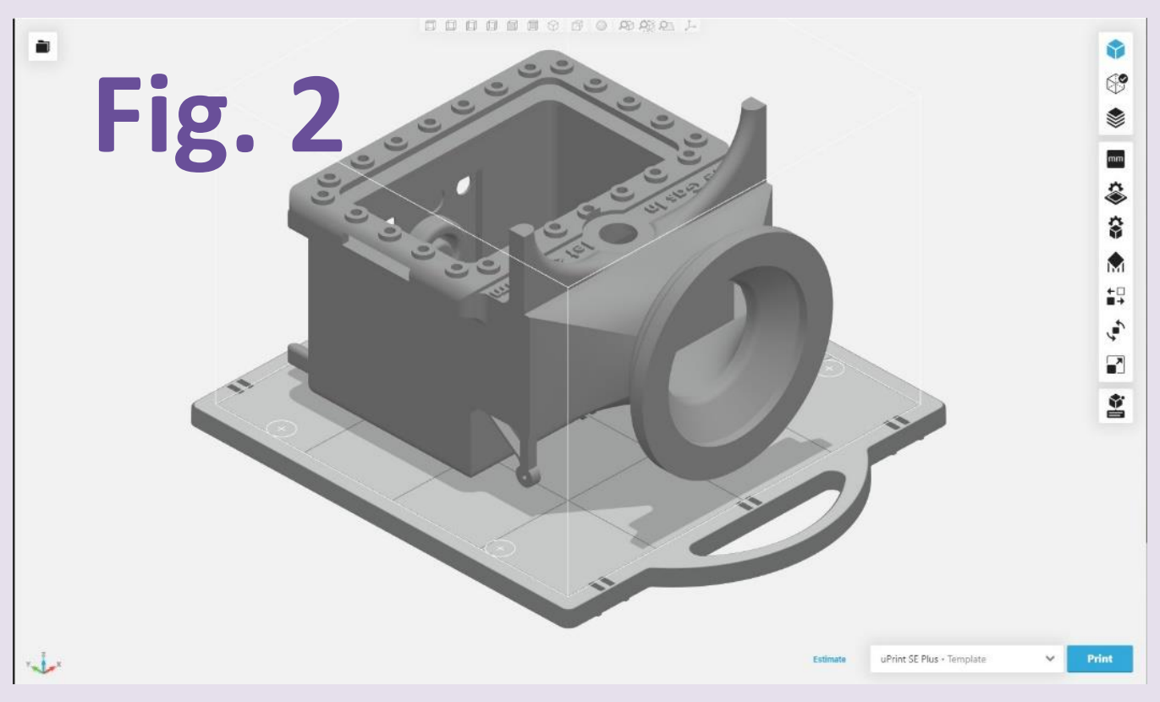
Fig. 2


Fig. 3

TOOL FREE OPERATION

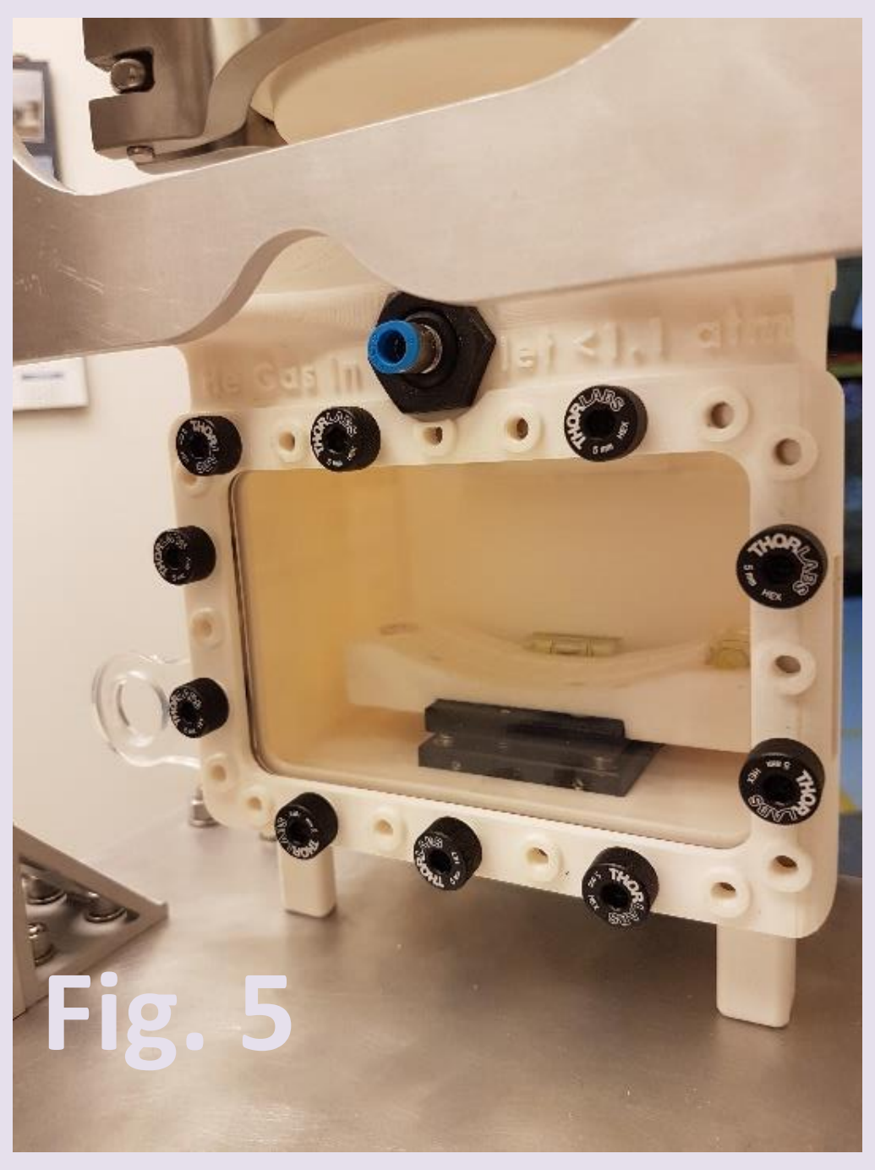
Fig. 5

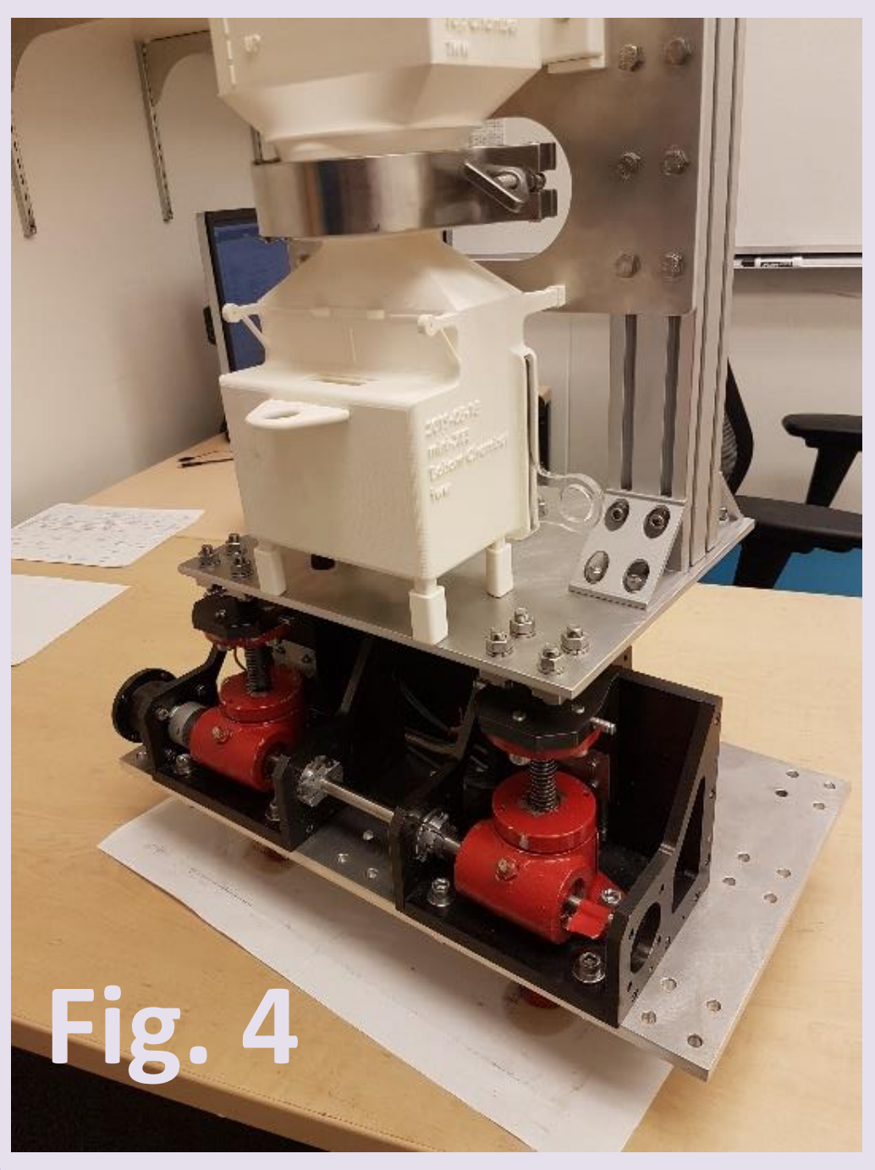
Fig. 4

From the very beginning, the design was trying to achieve no tools assembly, alignment, and operation. Two main parts are connected by NW-80 flange design (Fig.4) and the back-door window locks using thumbscrews (Fig.5). We use level vials for initial horizontal adjustment of the crystal holder. For higher 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 chamber has several slots for apertures, and alignment posts which combined with the alignment lines help to position the sample at the right location.

COMPLETED ASSEMBLY

The mini-XES is attached to an external aluminum 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.

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. The bottom chamber is more complex (Fig. 2).


Fig. 6

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.

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.

The back door was made out of Lucite (PMMA) plate (0.25” thick). The door has an O-ring installed and it is pressed against the chamber wall using thumbscrews A quick disconnect port for the He supply line is located above the back door (Fig. 5).

FIRST TESTS

The device works! (Fig. 7 – Fluorescence Spectrum of the Fe_2O_3 nanoparticles, 20-50 nm diameter). 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 height should be optimized. It would be helpful if the detector had some vertical adjustment.

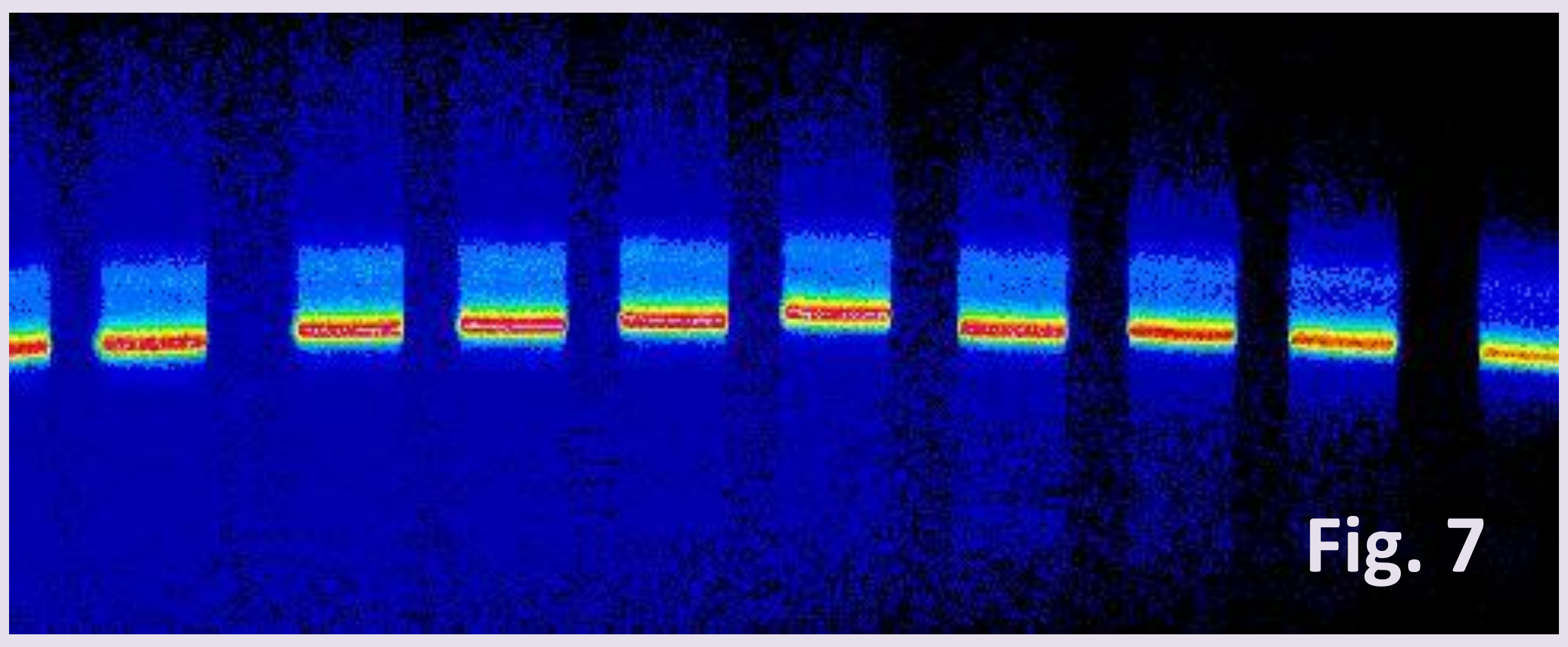
Fig. 7

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.

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WEPC04 / ID 1601