Mechanical Design of a Triple-Collimator for Macromolecular Crystallography

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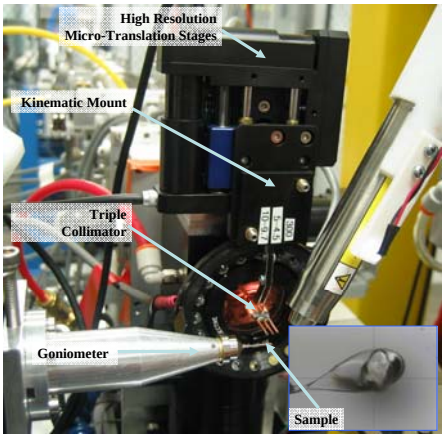
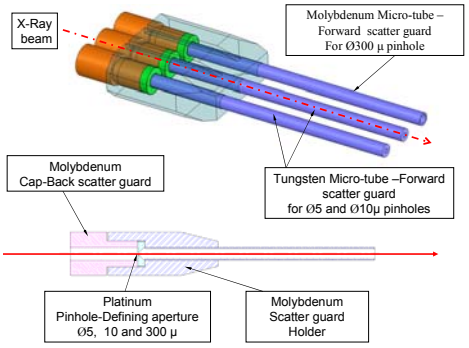
Abstract

A multifunctional triple-collimator has been developed at GM/CA-CAT at the Advanced Photon Source (APS), Argonne National Laboratory. The triple-collimator assembly consists of three sets of pinholes and scatter guards, a kinematic mount, and a high precision XY positioning system. The unique functions of the triple-collimator assembly include:

- Acts as a beam defining device with either a 5 or 10 micron pin hole providing a small, clean beam from the focused beam.
- Serves as a scatter guard for the full focused beam (25 x 70-120 microns^2) or beam defined by upstream slits using a 300 micron pinhole to significantly reduce hard x-ray background scattering.
- Provides rapid-interchange of the three collimators described above with high repeatability and stability.
- The kinematic mount allows the triple-collimator to be removed and re-installed with micron precision.
- Triple-collimator is also used for automated beamline alignment.

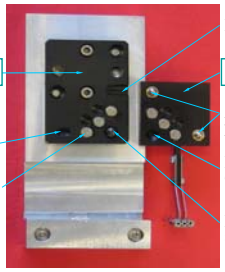
A Triple Collimator with Kinematic Mounting on the On-Axis Visualization system at GM/CA





Schematic diagram of the triple collimator. Each collimator consists of a beam-defining pinhole, a forward-scatter tube and a backscatter guard. These are mounted in a three-way Molybdenum scatter guard.

Alignment-tools and Test results of kinematic mounting



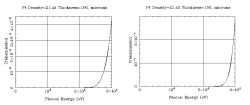
Pre-alignment jig: Align tubes and guard holder relative to Kinematic base

The positional reproducibility of the mini-beam collimator on the kinematic mount was measured by optical metrology. The RMS deviation from the mean position was 0.24 µm in both the X- and Z-directions for 34 repeated manual mount and dismount operations. The stability of the assembled mount was monitored in the X-direction once per minute over a period of 20 minutes. The RMS deviation from the mean X-position was 0.06 microns. The stability in the Z-direction was not measured, but is expected to be smaller than the X-direction.

Precision-alignment setting:

The optical axes of the three tubes are adjusted to be co-parallel and reside in the same plane using the microscope before gluing.
The triple collimator is mounted on XY stages under the OLYMPUS SZX12 microscope.

X-ray Shielding Material study



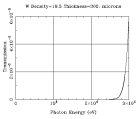
The X-ray transmission through 100 and 150 µm thick Pt at 12KeV is $<10^{-14}$

The mini beam size is defined by a 2mm diameter platinum disk with a pinhole in the center. The disk is 600 µm thick and tapers to 100-150 µm at the position of the aperture. The calculation results on the left, show that the transmission is negligible at 12 keV.

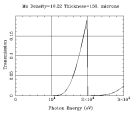
A long thin tube defines the exit aperture for forward scatter from the pinhole and minimizes air scatter between the pinhole and the sample.

The tubes are made of tungsten or molybdenum of varying OD/ID to best match the size of the pinhole. Tungsten tubes with an OD of 1.00 mm, ID of 400 µm, and a wall thickness of 300 µm are used for the 5 µm and 10 µm pinholes. For the 300 µm pinhole a molybdenum tube with an OD of 1.05 mm, ID of 790 µm, and wall thickness of 130 µm is used. The graphs on the right show the effectiveness of the tube walls in stopping 12 KeV x-rays.

When the device is fully assembled, the backscatter guard, pinhole, forward-scatter tube and bullet-shaped scatter-guard form a compact well shielded mini-beam collimator .



Transmission through 300 µm W tube wall At 12keV is $<10^{-14}$



Transmission through 130 µm Mo tube wall at 12keV is 0.00132

References

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Applications: Mini-beam collimator enables micro-crystallography experiments on standard beamlines

Full focused beam | 10µ beam | 5µ beam

Pin hole Diameter (µm)	Beam size, FWHM(VxH) (µm)	Intensity (photons/sec/100mA)
5	5.0 x 5.1	7.8 x 10^{10}
10	10.5 x 10.8	2.0 x 10^{11}
Full beam	25 x 70	2.0 x 10^{13}

Beam imaged on a YAG crystal mounted at the sample position. The pinhole selects the central part of the focused beam.

The mini-beam has been successfully implemented at GM/CA CAT. The triple collimator provides a choice of a 5 micron beam (FWHM) with an intensity of ~7x10^{10} photons/sec, a 10 micron beam (FWHM) with an intensity of ~2x10^{11} photons/sec, and a fully focused 25x70 micron beam with an intensity of ~ 2x10^{13} photons/sec.
Many users desire the ability to switch back and forth between "full beam" and "mini-beam" depending on the size and nature of their crystals. We have designed and implemented a versatile system that makes switching possible with the click of a button in our user-friendly Blu-Ice GUI software.
Since the implementation of the triple collimator, about 80% of users use the mini-beam for data collection.

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