Performance of the Compact Visual Beam Imaging System on the GM/CA BM Beamline at the APS

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Abstract. A typical problem encountered on a beamline with a sagittal focusing monochromator is the difficulty of optimizing the crystal alignment because the full width of the monochromatic, unfocused beam cannot be visualized. This problem is particularly acute on beamlines that accept a wide swath of radiation combined with a fixed experimental setup consisting of constrained apertures that only allow the focused beam to pass through to the sample position. To address this problem, an imaging system has been designed and implemented on the GM/CA bending magnet beamline at the Advanced Photon Source, Argonne National Laboratory. This imaging system consists of a 30mm x 50mm flat YAG crystal, right angle prism/mirror and video camera located downstream of the vertical collimating mirror, sagittally focusing monochromator and vertical focusing mirror. The YAG crystal was installed in a 6-way vacuum cross in the beam path, and was mounted on a linear translation feedthrough allowing remote controlled insertion and removal of the crystal from the beam path. The CCD camera was mounted outside the vacuum chamber and views the x-ray induced scintillation from the YAG crystal through a window. This visualizer allows one to optimize the twist, yaw and roll of the second crystal, facilitates proper sagittal focusing and serves as a remote controlled diagnostic tool. An overview of the design and the performance of the imaging system will be presented.

Keywords: imaging system, diagnostics, beam alignment

PACS: 07.85.Qe

1. Introduction

GM/CA obtains its name from its two supporting institutes, the National Institute of General Medical Sciences (GM) and the National Cancer Institute (CA). It operates a Structural Biology Facility consisting of three synchrotron radiation beamlines at the Advanced Photon Source. Since 2007, a compact YAG (Chromium Doped Yttrium Aluminum Garnet - Cr4+:YAG) Imaging System (YIS) has been designed and implemented as a diagnostic tool for visualizing monochromatic x-rays emanating from the first fully tunable hard x-ray dual-canted undulator [1]. Each of the undulators serves as a source for two independently operated beamlines in the sector 23 at the APS [2]. The YAG imaging systems have greatly facilitated beamline commissioning as well as sample alignment to the x-ray beam in the macromolecular crystallographic endstation.

A new YAG imaging system has been designed and constructed for use as a diagnostic for sagittal focusing (Figure 1) at the Bending Magnet (BM) beamline. It replaces a temporary setup located in an upstream position of the experimental endstation. The setup fits between a visualizer located upstream after the vertical focusing mirror and the on-axis visualizer at the sample position. This enables us to quickly check and adjust horizontal focusing with the fast data collection shutter closed, thus protecting the sample. The YAG/BPM setup provides beam position diagnostics in the endstation, greatly simplifying delivering the focal beam to the sample position.
2. Design of the YAG Imaging System

The BM beamline presents a different set of design specifications relative to the undulator beamlines. In the case of the undulator source, the size (FWHM) of the unfocused beam at the sample position is on the order of approximately 2 mm, for the bending magnet beamline a maximum horizontal fan of 1.1 mrad of radiation leads to a beam size of 44 mm at the sample. The optical set-up of the GM/CA
BM beamline consists of a collimating mirror, a double crystal monochromator and a vertical focusing mirror (see Fig. 1). The increase in beam size of over an order of magnitude necessitates a larger viewing area and fiducials to measure, position and level the beam. In order to accommodate the larger viewing area a 30mm x 50mm flat rectangular YAG crystal was cut from a commercially available 50 mm diameter disc. A Cr grid scale was printed on to the YAG surface using laserwriter lithography. A right angle prism/mirror and video camera GC1290 from Allied Vision Technologies Inc. with lens (50 mm f/1.4) complete the system (Figure 2).

The YAG crystal assembly was mounted on a motor driven linear translation feedthrough and installed in a 6-way vacuum cross in the beam path allowing remote insertion and removal of the YAG crystal from the beam path. The video camera was mounted outside the vacuum chamber and views the x-ray induced scintillation from the YAG crystal through a window.

3. Performance of the YAG Imaging System

![Beam focused in the Vertical direction](image1)

YAG Grid | Unfocused Vertical | Focused in the Vertical | Beam focused at Sample Position

**Beam focused in the horizontal (Sagittal) direction**

Unfocused Horizontal | Partially Focused | Focusing in Horizontal

**Diagnostic for Second Crystal in incorrect position**

Twist, Yaw and Roll Errors | Twist and slight Yaw Errors | Twist Errors seen before correction

Beam properly focused at YAG Position

Figure 3: The images on the YAG of BIS

The BIS enables visual optimization of the twist, yaw and roll motions of the monochromator second crystal. Examples of its use in the focusing process can be seen in Figure 3. The images in the first row of Figure 3 (the description of the images go from left to right) illustrate two features, its use in focusing in the vertical direction and in positioning the beam in the horizontal direction. In this case the beam is aligned off of the center mark of the YAG. The 2nd row shows a smooth transition from a slightly bent crystal to a radius that is close to the value at which the focus is at the sample. Notice that the ribs of the sagittal crystal are aligned parallel to the vertical fiducials. In the third row, the first two images result from a crystal that is partially bent with yaw, twist, and roll errors. The effects of these problems result in only a portion of the crystal satisfying the Bragg condition (uneven brightness of the beam on the YAG), the ribs visually tilted relative to the grid and the entire beam located off of the previously aligned position in the horizontal direction. The remaining 3rd row images show that the twist and yaw adjustments can be finely tuned to produce a horizontally focused beam. This enables us to quickly check and adjust horizontal focusing with the fast shutter closed, thus protecting the sample.
4. Summary

Protein crystallography beamlines continue to offer new user conveniences, some of them impose new restrictions in the beam delivery pathway. One of these indispensable new features is the On-Axis Visualizer (OAV). In the case of the smaller beam sizes of the undulator beamlines this has not been a problem. For the larger beam sizes of a bending magnet source, it is another obstacle between source and sample. To aid in circumventing this restriction a compact YAG visualizer has been modified to expand its capabilities to include a larger horizontal and vertical viewing area and a fiducial grid while maintaining its compact footprint. These improvements were necessary to customize its use for characterizing the sagittal focusing second crystal in the double crystal monochromator that is used in the Sector 23 bending magnet beamline.

The expanded field of view allows the staff to see approximately 30 mm (0.8 mrad) of a possible 1.1 mrad of radiation in the horizontal direction. Yaw, twist and roll errors can be visualized and corrected at an early stage in the focusing process. These corrections can be made to accommodate focusing at the visualizer and aid shifting the focus to the sample position.

In addition to the expanded viewing area, Cr fiducials have also been added to the YAG crystals. These fiducials are invaluable as references in centering the beam in the horizontal direction and in minimizing the twist in the sagittal focusing crystal.

Reference from published papers:

[1] S. Xu, R.F. Fischetti, R. Benn and S. Corcoran “Design and performance of the compact YAG imaging system for beamline diagnostic at GMCA beamlines at APS” 2007 American Institute of Physics 978-0-7354-0373-4/07, Volume 879, P1403-P1406
[2] R.F. Fischetti, S. Xu, et al., “Optical performance of GM/CA-CAT canted undulator beamline for protein crystallography” 2007 American Institute of Physics Volume 879, P754-P757

Acknowledgments

GM/CA @aps is supported by Federal funds from the National Cancer Institute (Y1-CO-1020) and the National Institute of General Medical Science (Y1-GM-1104). Use of the Advanced Photon Source was supported by the U.S. Department of Energy, Basic Energy Sciences, Office of Science, under contract no. W-31-109-ENG-38.

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