Design and Performance of the Compact YAG Imaging System for Diagnostics at GMCA Beamlines at APS

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Abstract. A compact YAG (Chromium Doped Yttrium Aluminum Garnet - Cr4+:YAG) imaging system has been designed as a diagnostic tool[1][3] for monochromatic x-rays emanating from the first "Hard" x-ray dual-canted undulator at the Advanced Photon Source at Argonne National Laboratory[4]. This imaging system consists of a flat YAG crystal, right angle prism/mirror, video camera and monitor [2]. A flat YAG crystal with a diameter of 10 mm has been installed in vacuum and positioned downstream of the monochromator of the insertion device beamline. Another 20 mm diameter YAG crystal has been installed in vacuum after the horizontal deflecting mirrors of the second insertion device beamline. CCD cameras are mounted in air close to the window of the vacuum ports to image the fluorescence of the YAG crystals. An additional 25 mm diameter YAG crystal has been used for K-B (Kirkpatrick-Baez) mirror focusing and beamline alignment. These YAG imaging systems have greatly facilitated beamline commissioning as well as sample alignment to the x-ray beam in the macromolecular crystallography endstation. An overview of the optics design, mechanical design and the performance of these devices will be presented in the paper.

Keywords: YAG, diagnostics, alignment.
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INTRODUCTION

A new macromolecular crystallographic facility developed by GMCA CAT has begun operations at the Advanced Photon Source (APS). The facility consists of three beamlines; the world's first pair of fully tunable "hard" dual-canted-undulator beamlines and one bending magnet beamline. The canted undulator geometry has the potential to double the scientific throughput of synchrotron facilities. The independently tunable ID beamlines are operational, and the bending magnet beamline is being commissioned. A compact YAG (Chromium Doped Yttrium Aluminum Garnet - Cr4+:YAG) imaging system has been designed as a diagnostic tool for monochromatic x-rays emanating from the two canted undulator[4]. These YAG imaging systems have greatly facilitated beamline commissioning as well as sample alignment to the x-ray beam in the macromolecular crystallography endstation.

The beamlines have been design for ease of use and rapid alignment. An imaging system is installed in vacuum after optical component on the ID-lines allowing visual inspection of the beam position shape and intensity. Fig. 1 shows two insertion device beamlines from the dual canted undulators and the locations of the installed YAG image systems.

The location, application, diameter and thickness of the YAG crystals are listed in Table 1. The locations of the YAG beam monitors are summarized in column 2. Three sets of YAG imaging system were used for beamline commissioning, five sets were installed on in vacuum beam position monitors (BPMs), and two sets are used for sample alignment at ID experiment stations. The YAG system can be used as tools to help align mirrors to the X-ray beam. In this application, it is beneficial to be able to see the beam before the mirrors intercept the beam and after they deflect it. Therefore, 20 mm diameter YAG crystal has been placed in the vacuum system after the horizontal deflecting mirrors and the Kirkpatrick-Baez (K-B) focusing mirrors. Larger 25 mm diameter YAG crystals are incorporated in the compacted set of YAG imaging system.

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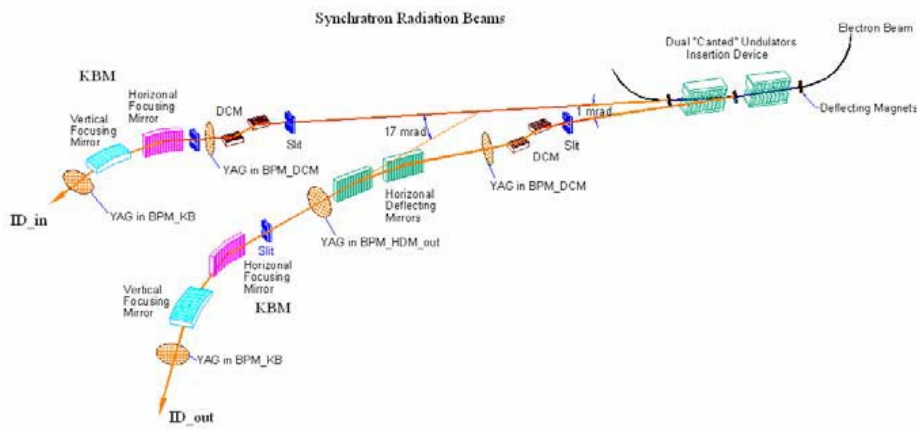

FIGURE 1. Schematic of canted ID beamlines and YAG imaging system at GMCA CAT at the Advanced Photon Source.

TABLE 1. List of YAG image systems installed at the three beamlines of GMCA CAT at APS

YAG	Location	Vacuum or in Air
Ø10mm X 100µ	BPM_DCM of ID_in Beamline	UHV
Ø20mm X 200µ	BPM_K-B, of ID_in Beamline	UHV
Ø10mm X 100µ	BPM_DCM of ID_out Beamline	UHV
Ø20mm X 200µ	BPM_HDM of ID_out Beamline	UHV
Ø20mm X 200µ	BPM_K-B of ID_out Beamline	UHV
Ø20mm X 200µ	ID_in Station for commissioning	In Air
Ø20mm X 200µ	Sample position of ID_in for alignment	In Air
Ø20mm X 200µ	ID_out Station for commissioning	In Air
Ø20mm X 200µ	Sample position of ID_out for alignment	In Air
Ø20mm X 200µ	BM Station for commissioning	In Air

OPTICS DESIGN OF THE YAG IMAGING SYSTEM

The YAG imaging system consists of a flat YAG crystal, right angle front surface mirror or flat mirror, video camera and monitor is shown in Fig.2. Two types of YAG imaging systems that have been used for commissioning and alignment of beamlines are shown in Figure 3. The set up on the left is a very compact system using just a CCD camera, lens and a block to hold the YAG crystal and a mirror. The system sits on a miniature rail for easy transportation and can readily be mounted on a platform to monitor the X-ray beam. The overall dimensions of the YAG system are 150 mm x 38 mm x 76 mm. All components are connected together by a block that has C-mount threads. The 25mm diameter YAG is glued into a C-mount ring that is then screwed into the block. A C-mount collar screws in to the block perpendicular to the YAG. The lense of the camera slips into the collar and is held with set screws. The CCD camera is directly connected with the objective lens A protected aluminum-coated first surface mirror (35mm x 35 mm x 3 mm) is positioned in the housing at 45 degrees relative to the incident beam. The compact YAG imaging system mounted on XY stages for ID beamlines commissioning and alignment.

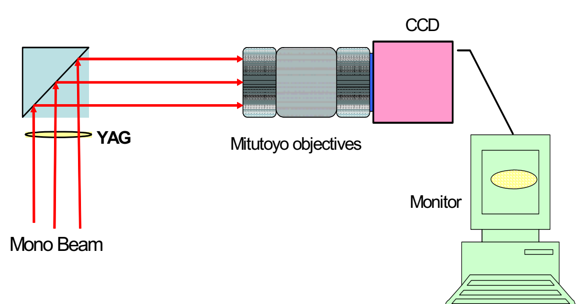

FIGURE 2. Schematic of YAG imaging system.

The right-hand picture in Figure 3 shows a set up used for the bending magnet beamline commissioning. The unfocused monochromatic beam is almost 50 mm wide in the experimental station. It is desirable to see the entire beam so a 50 mm diameter YAG is used here. A large mirror prism (50 mm X 50 mm X 71 mm) servers as a front surface mirror so the camera can view the beam from the side, thus protecting the lens form radiation damage.

FIGURE 3. Left-hand of figure 3 is a compact imaging system for ID beamlines commissioning and alignment. The Ø25 mm YAG crystal, flat mirror, video camera were mounted on the PRL-6 rail. Right-hand of figure 3 is a set-up for bending magnet beamline commissioning and alignment. The Ø50 mm YAG crystal, right angle mirror and camera were mounted on the base plate which installed on PXY stages

MECHNICAL DESIGN OF THE YAG IMAGING SYSTEM IN VACUUM

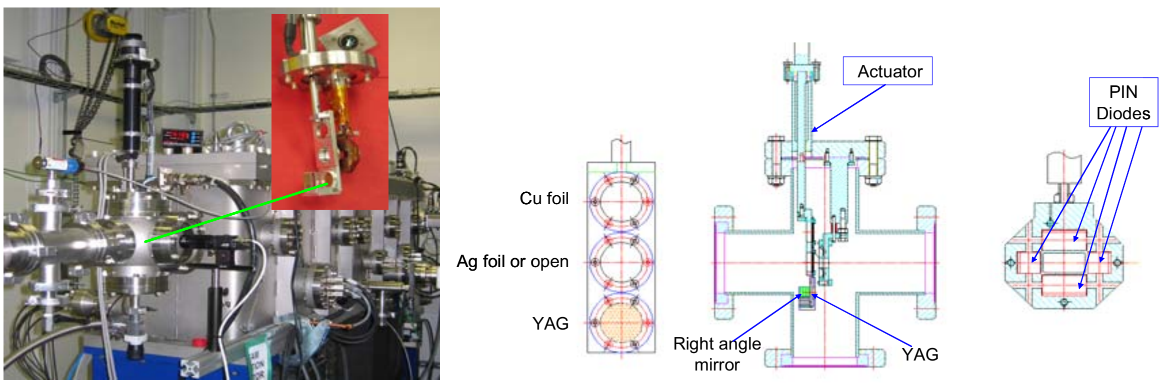

FIGURE 4. YAG crystals of various diameters have been installed in the UHV vacuum system of the two ID-beamlines just downstream of the major optical components (monochromators, horizontal deflecting mirrors and K-B focusing mirrors). A CCD camera mounted outside the vacuum system monitors the fluorescence form the YAG crystal through a viewport. The right drawing shows a flat Ø10 mm YAG crystal and a 10 mm X 10mm X 14 mm right angle mirror have been installed in the vacuum chamber

The YAG systems are attached to the beam position monitors that providing intensity and positional read outs. The beam position monitor (BPM) has to comply with high vacuum requirements because it is integrated into high vacuum sections. Four photodiodes are arranged around the beam facing downstream (Fig. 4 right picture). The beam passes through a thin foil fluorescence or scattering that is continuously monitored by the photodiodes. The photo current from each diode is analyzed to extract the beam position. The device is based on a NW 63 CF 6-way cross (standard) see Fig. 4 (middle picture) and on a NW 100 CF cross needed for the BPM-DCMs and the BPM-HDM-1. In general, two ports of the cross are for beam entrance and beam exit, one port will serve as access for the diode holder and the target foil translation, and additional ports are for survey of the diode. Copper and silver foils are mounted on the first and second positions of the holder. A YAG image assembly was installed on the bottom port of the holder (see Fig 4 left picture of right drawing) which on the actuator will provide enough yields. The distance between the two ports is 30.5 mm. The stroke of the actuator allows the foil assembly and the YAG assembly to be pulled out of the direct beam. These YAG imaging systems have greatly facilitated beamline commissioning

The requirements are similar for the monitor after the HDM, for which both beams, ID-in and ID-out, have to be accounted. In addition, when using the monitor for the HDM alignment, both, the diode holder and the foil translator, have to accommodate a beam travel range of the deflected ID-out beam from 0 mrad to 16 mrad. The 20 mm diameter YAG has installed for accepting the beam.

Fig.5 shows the simultaneous observation of monochromatic X-rays from the dual-canted undulators. The picture shows the images of monochromatic X-ray from the first "Hard" dual-canted undulators on the YAG crystals (February 17, 2005). In the left image the YAG shows monochromatic X-rays from the downstream

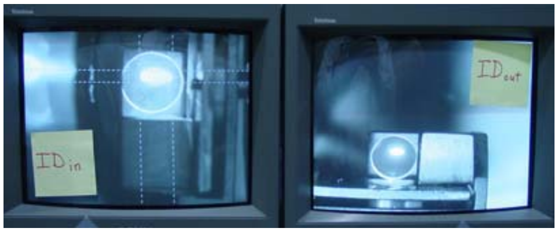

FIGURE 5. Simultaneous Observation of Monochromatic X-rays from the 1st "Hard" Dual-Canted Undulator

YAG FOR SAMPLE ALIGNMENT AND CENTERING

These YAG imaging systems are routinely used to align the X-ray beam and the sample. The end station goniometer has a high magnification optical system for viewing and centering the sample. The optical system has a hole along the optical axis through which the X-ray beam passes. One can align the X-ray beam and the optical axis of the camera by placing a YAG on the goniometer at the sample position and centering the image of the beam on the cross hairs as indicated in Fig. 6. In the upper right picture the X-ray beam is misaligned. The lower right picture shows a beam properly aligned to the cross hairs. Once the ebam and the cross hairs are aligned the sample can be mounted instead of the YAG and easily aligned to the X-ray beam by centering it on the cross hairs.

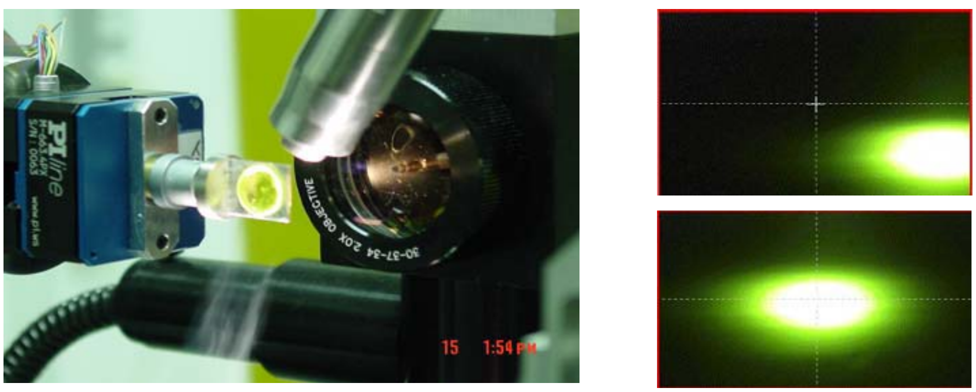

FIGURE 6. The picture on the left shows a Ø10 mm X 100 μm YAG crystal mounting at sample position. The top right and lower left pictures are images of the beam captured with a video frame grabber.

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