

Imager Fiducialization For Automatic Beam Alignment

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Introduction

The Automatic Beam Alignment system (Skywalker) autonomously performs the beam alignment operations for hutches. The beam is aimed by positioning the undulators and the Hard-xray Offset Mirror System (HOMS). The beam's transverse position is measured by inserting Yttrium Aluminum Garnet (YAG) targets into the beam path and viewing the fluorescence pattern with a camera. By using two imagers at different z positions, the beam pointing and beam position can be established. Once this is known, the HOMS can be iteratively adjusted (or "walked") to correct the beam's alignment. The beam pointing is critical for the function of downstream optical components and thus beam delivery.

Keywords: beam alignment, OpenCV, Camera Tracking, Bluesky, Ophyd, Skywalker, YAG, Diffraction

Problem Statement

Aligning the beam depends on the ability to precisely measure its transverse position. The imagers allow the beam's position to be measured but obstruct the beam. To accommodate for this, the YAG screens are retractable and have configurable cameras. This means they do not reliably return to the exact same location or zoom each time. Before the imagers are able to accurately measure beam position, the imagers' inconsistent setup must be measured and accommodated for.

Solution Principal

Without calibration the Skywalker system is typically capable of placing the beam on the YAG by using the target pixel positions of the beam from previous alignments. This procedure brings the beam roughly to the center of the YAG but can only be as accurate as the YAG's positioning. This is typically close enough for the slit scanning procedures to take over.

The slits device creates a rectangular aperture of controlled dimensions and location. The slits are highly consistent. By narrowing the slits about the laser, the image of the laser on the YAG is cropped to a rectangle of precise dimensions and location.

Having both the pixel dimensions and the physical dimensions of the same beam profile allows the pixel measurements to be mapped to usable spatial measurements.

Implementation

I accomplished this task using python with NSLS's Ophyd and Bluesky modules. Ophyd helps create python objects for manipulating and reading EPICS devices. Bluesky provides tools for scheduling instructions to EPICS devices and collecting data. Python's OpenCV libraries are used for collecting the image measurements.

The first part of my work consisted of adding functionality to the python devices so they could carry out the necessary operations. These tools allowed Bluesky plans to reset their devices after execution with only a decorator and connected slit control with standard routines for single variable devices.

I then wrote Bluesky plans to execute the fiducialization procedure:

1. Insert YAG in beamline with test beam or x-ray.
2. Close slits to partially obstruct beam. See Fig 1,2.
3. Take measurements of
 - a. Beam Centroid: center position of the beam
 - b. X,Y widths of beam profile.

Images

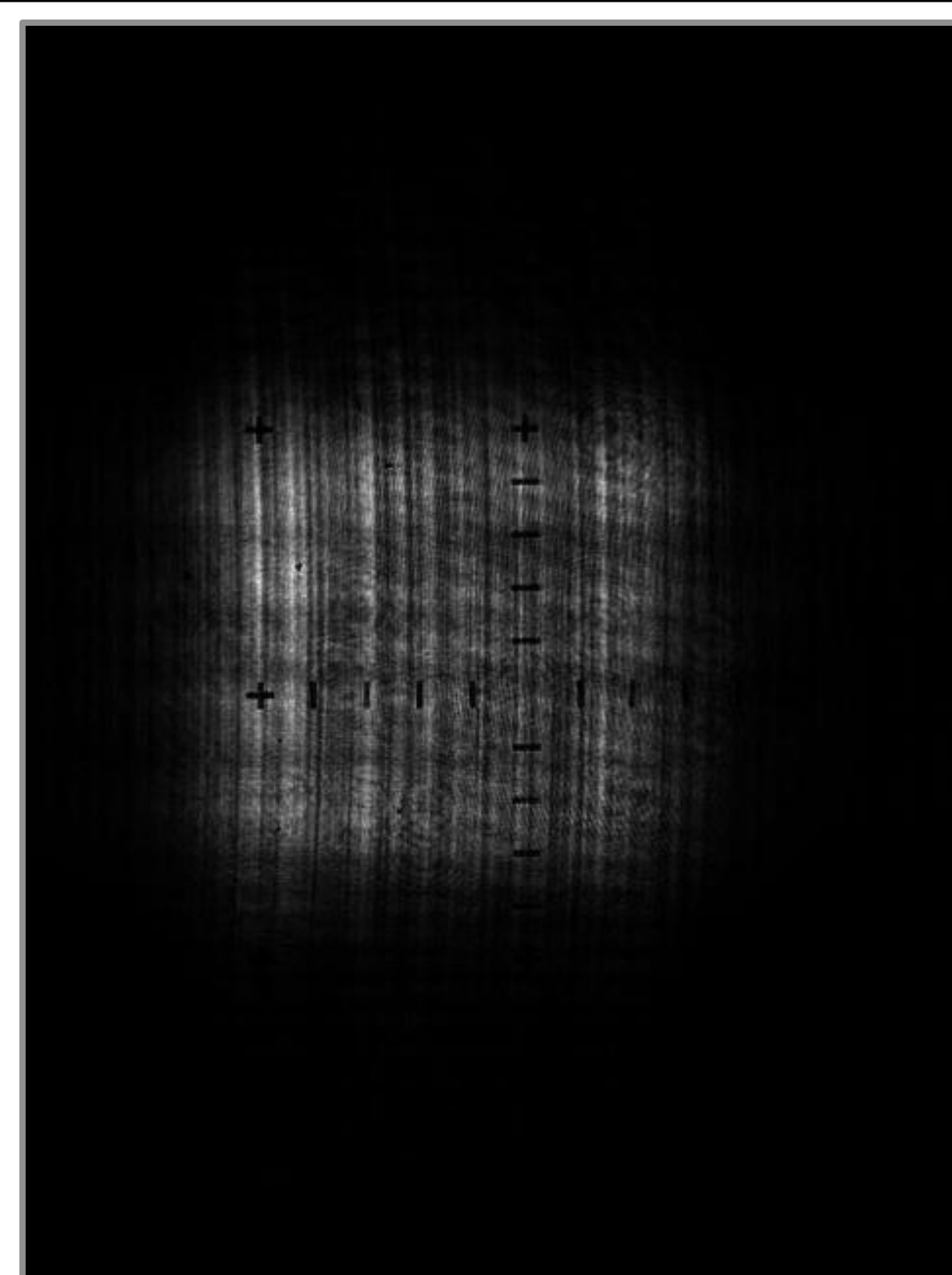


Fig. 1: An image of the test beam passed through 2.0 mm² opening.

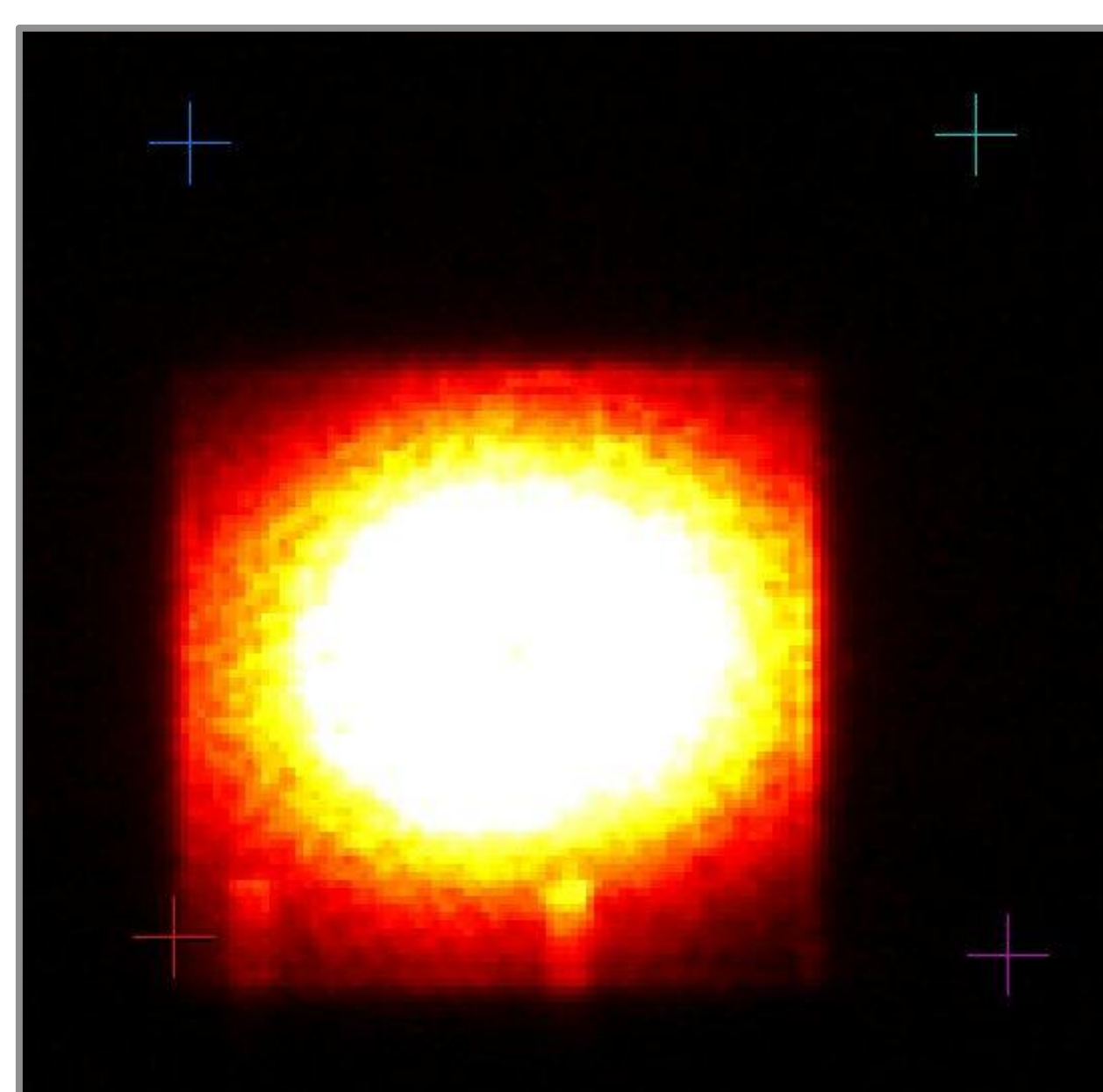


Fig. 2: An image of the X-ray beam on MFX's DG2 YAG. Note the rectangular cropping is much cleaner than the test beam.

Future Development

Early testing with the reference laser in MFX showed signs of diffraction. This occurred when the slits were closed down to <.5mm widths as seen in fig. 3. While centroid data is likely still accurate, measurement of the beam profile width are affected. To avoid this issue, X and Y length measurements may be taken by moving the aperture a small distance and measuring displacement instead of the area dimensions.

A second issue was theorized to occur if the beam was not sufficiently close to the slits' center. In this situation the centroid would not report the center of the slits and the w/h measurements would be incorrect. This could be rectified by changing the aperture size and noting the change in centroid position.

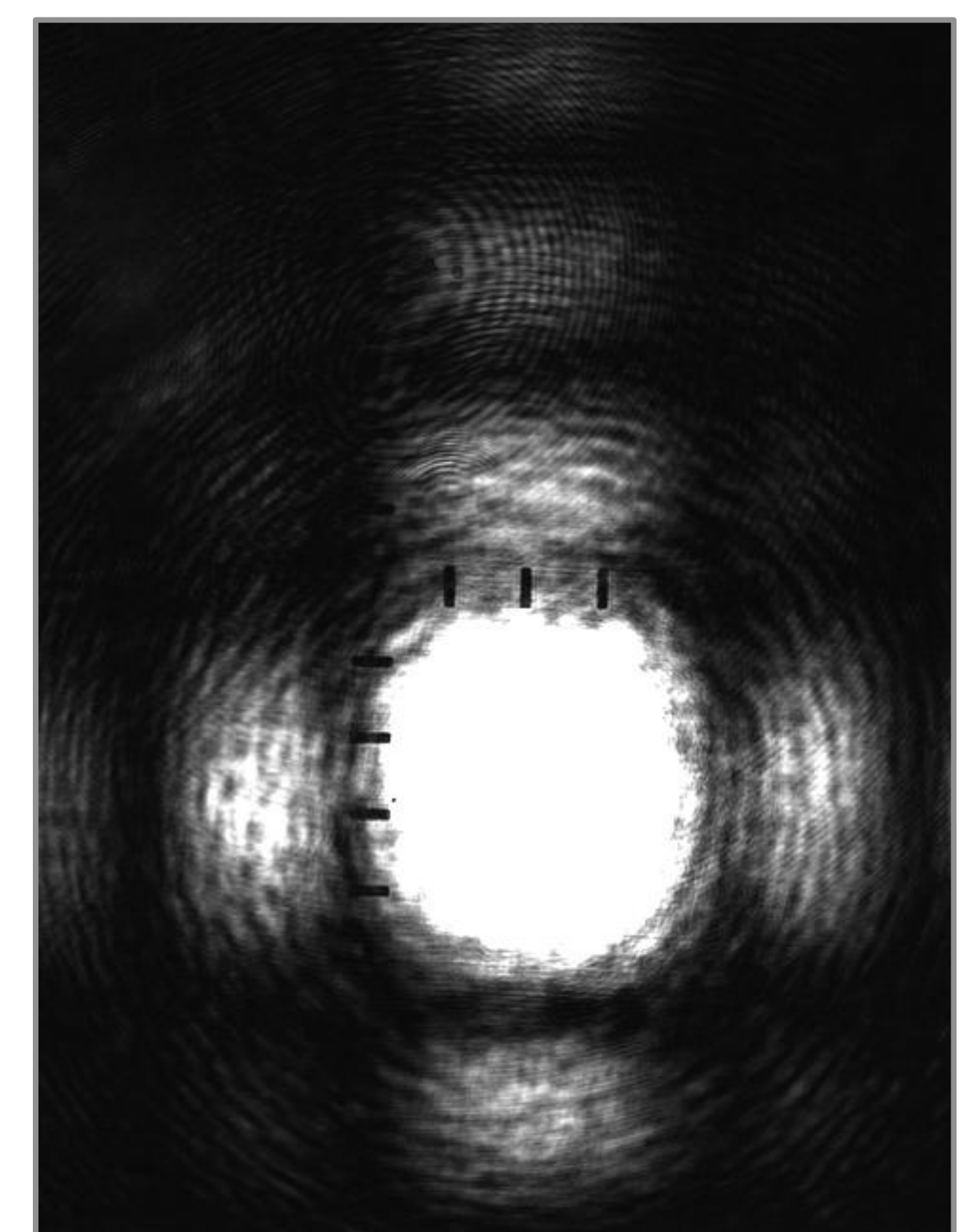


Fig. 3: An image of the test beam on MFX's DG1 YAG shows signs of diffraction.

Conclusions

Development of the fiducializing procedures allows calibration of the area detectors used by Skywalker. This prevents mobile imagers from introducing error into the alignment procedures.

Skywalker is currently undergoing its first deployment after which this toolset for autonomous beam alignment will be deployed on numerous other systems. The ability to accommodate for variations in hardware will be key in ensuring Skywalker's success and contribute to developing automated systems for L2S-I.

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