A White and Monochromatic X-ray Beam Imaging System

E. M. Dufresne, S. B. Dierker

Department of Physics, The University of Michigan, Ann Arbor, MI, U.S.A.

Introduction

It is quite helpful for alignment of optical elements, such as mirrors or perfect crystals, to record the fluorescence of an x-ray sensitive screen with an imaging system. The APS undulator beam, at 60 m from the source, can be several mm across in the horizontal direction; thus a large field of view would be nice to have in an imaging system. One can level a mirror by overlapping the direct and reflected beams far away from the optics. An optical system with a good resolution is necessary if one wants to accurately zero the mirror incident angle. We describe below a system that can image a white or monochromatic undulator beam. It has a 4 to 5 mm field of view and a resolution of 10-20 µm. Nearly all the parts are commercially available, and the system costs about $1700 to make.

Methods and Materials

We have based our imaging system on a 20-mm-diameter, 0.5-mm-thick YAG:Ce doped single crystal that emits 550 nm light when hit with x-rays.[1] The YAG visible fluorescence is imaged onto an inexpensive TV camera using an optical system with a 1:1 magnification. Only the field of view of the camera here limits the optical system. Near unit conjugate ratio, it is well known that the best imaging system is a pair of achromats, with the object and image each set in the focal plane of the lenses. Figure 1 shows the viewing system. The optics are housed in a Thor Labs SM1 cage system. Each lens (Newport Corp PAC 052, 25.4 mm diameter, 100 mm focal length) is mounted in a fine-thread adjustable lens tube. The YAG is held in a small aluminium mount by a set screw, and a 1" diameter round mirror (Newport Corp. 10D10AL.2) is mounted in the cage system to reflect the light by 90 degrees. This is done to prevent the direct hard x-rays transmitted through the YAG from damaging the video camera. We have found it useful to add a diaphragm between the two achromats. To prevent saturation of the video camera signal, one often places thin metal foils in front of the YAG screen. For a white beam incident on the YAG, metal foils have the drawback of shifting the average energy of the spectrum towards higher energies. This can be a problem when looking for the reflected beam on a mirror since the low-energy x-rays are absorbed by the filter. We have solved this problem by using visible neutral density filters to reduce the light intensity on the CCD. The TV camera used is the 1/3" CCD Watec 502A or the new Watec LCL-903HS. The new Watec is recommended since it has a higher sensitivity (0.0002 vs 0.05 lux), a higher resolution (570 vs 400 TV lines), and a more robust BNC connection than the 502A.

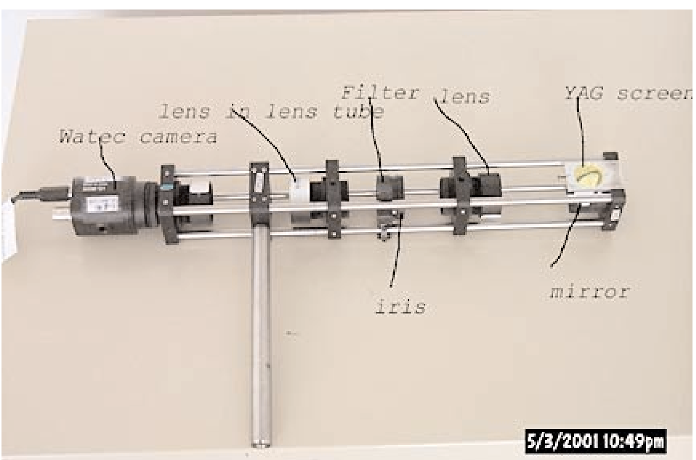

FIG. 1. A YAG:Ce single-crystal-based x-ray imaging system.

FIG. 2. A monochromatic x-ray beam profile in the 7-ID-C hutch.

Results

Figure 2 shows the 7-ID monochromatic beam profile, 50 m from the source. The x-ray energy was set to 10 keV. One can clearly see a fine spatial structure, which is evidence of the good resolution of the system. This spatial structure is believed to originate from speckle generated by the upstream Be and graphite windows, mostly located in the 7-ID-A and -B hutches. A white beam slit in the 7-ID-A hutch set to 0.5 mm by 0.5 mm limited the beam size on the YAG screen placed in the 7-ID-C hutch. The filter optical density (OD) required will depend on the x-ray intensity, thus on the location of the YAG screen in the beamline and the x-ray optics chosen. Typically for a Si (111) monochromatic beam, we use a filter with an OD=2.5, 31 m from the source with the Watec 502A. In the 7-ID-A hutch, a white beam can be observed at 29 m with a filter with an OD = 6.5.

Discussion

The optical system described above is used at MHATT-CAT in many applications, such as for looking at the monochromatic beam stability or for focusing or aligning x-ray optics. It is believed that the YAG thickness may blur the resolution. Thinner crystals or thinly doped YAG:Ce crystals are known to improve the resolution toward a few microns.[1,2] The inexpensive TV camera response is nonlinear. With a better quality CCD camera, the electronic nonlinearities can be removed, and the resolution could be improved to a few microns.

Acknowledgments

Operation of the MHATT-CAT sector 7 beamlines at the Advanced Photon Source is supported by DOE Grant No. DE-FG02-99ER45743. Use of the Advanced Photon source was supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Science, under Contract No. W-31-109-ENG-38.

References

[1] Star Tech Instruments (www.startechinst.com), model F20G YAG:Ce doped. They also stock 100-μm-thick YAG:Ce screens.

[2] A. Snigirev et al., J. Opt. Soc. Am. A **15**, 1940 (1998).