# High-Throughput X-ray Microtomography System at 2-BM

F. De Carlo,[1] Y. Chu,[1] D. C. Mancini,[1] B. Tieman,[1] S. Y. Wang[2]

[1] *Experimental Facilities Division, Argonne National Laboratory, Argonne, IL, U.S.A.*

[2] *X-radia, Inc., Concord, CA, U.S.A.*

## Introduction

It is now possible for large volumes of synchrotron-radiation-generated microtomography data to be produced at gigabyte-per-minute rates, especially when using currently available CCD cameras at a high-brilliance source, such as the Advanced Photon Source (APS). Recent improvements in the speed of our detectors and stages, combined with increased photon flux supplied by a newly installed double-multilayer monochromator, allow us to achieve these data rates on a bending magnet beamline. The ability to provide to the user a fully reconstructed data set in few minutes is one of the major problems to be solved when dealing with high-throughput x-ray tomography. This is due to the complexity of the data analysis that involves data preprocessing, sinogram generation, 3D reconstruction, and rendering. At the APS, we have developed systems and techniques to address this issue.

## Tomography System

### *Setup*

For the standard tomography setup used at 2-BM, the monochromatic beam produces an absorption contrast image on a scintillator screen. A CCD camera acquires the visible light image produced on the scintillator screen for each rotation of the sample around the Y-axis. Typically we acquire 1024x1024 pixels projection every 0.25 deg. This produces 720 projections. Once the data set is available, the preprocessing removes the white field and corrects for the dark field, as well as centers the rotation axis on the CCD.

### *Acquisition System*

The CCD Camera systems currently in use at 2BM are:

- PI ST-133 with 12 bits/pixel at 1 MHz. The CCD uses a Kodak chip with 6.8 µm - 1317x1035 pixels.
- Photometrics CoolSNAP Monocrome with 12 bits/pixel at 5 MHz. The CCD (Sony 4.65 µm - 1392x1040 pixels) is cooled to –25°C, and it has a readout noise of 14 e-rms.
- QImaging MicroImager II with 12 bits/pixel at 20 MHz able to produce 12 fps full frame; 20 fps with 2x2 binning; 40 fps with 4x4 binning.

All cameras use a Zeiss lens system (1.25x, 5x, 10x, 20x, 40x, 63x) in the standard AXIOPLAN microscope configuration.

The scintillators available are $CdWO_4$- and Ce-doped YAG (1 and 5 µm) on YAG. The resolution for a typical setup is ≈ 3 µm ($CdWO_4$ - 5x - N.A. 0.1) and ≈ 1.5 µm (YAG - 10x - N.A. 0.2).

### *MPI System*

The Message Passing Interface (MPI) standard is a library specification for message passing designed for both massively parallel machines and workstation clusters widely available, with free and vendor-supplied implementations. The key benefits of the MPI standard are its portability (Unix, FreeBSD, HP-UX, IRIX, LINUX, Solaris, SunOS, Windows 95/NT, MAC OS) and ease of use.

For our implementation of the MPI standard we used MPICH. It was chosen to implement a client server model for performing reconstructions. In this model, a single process acts as a server to hand out jobs to many clients running on separate Linux workstations on a dedicated subnet (see Fig. 1).

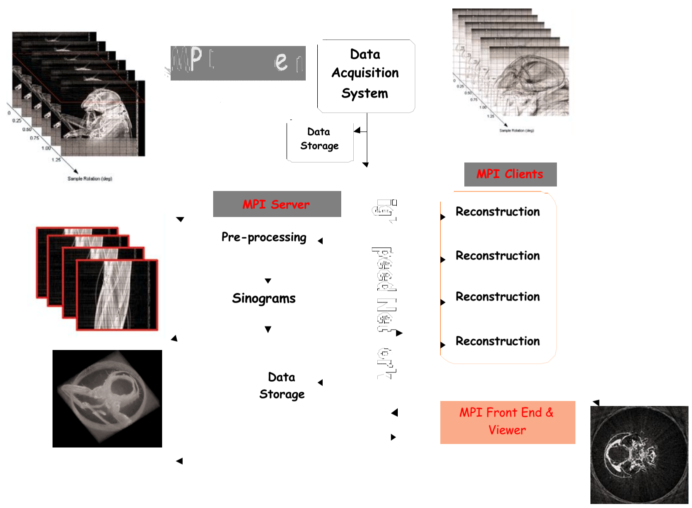


*FIG. 1 - The MPI system at 2-BM.*

The clients are typically the calculation engines of the system. The clients perform a simple loop of operations: request a new sinogram, perform the reconstruction of the sinogram, send the server the completed reconstruction, and request a new sinogram. The clients perform these tasks in parallel to one another, since each client is typically running on its own processor.

The server's job is to respond to requests from the various clients and coordinate the flow of data from the disk system over the network and back to disk. The server first creates a number of sinograms from the preprocessed files on disk. Once this is done, it waits for individual clients to make requests. The sinograms are handed out on a first- requested, first-served basis to the clients. The server also performs the task of collecting the completed reconstruction and writing it to disk. A specialized client has also been written to serve as a front end to the system. The front end makes requests of the server to alter various system parameters or to get information to display to the user about the current state of the system.

The performance of a dedicated VA Linux cluster (6 dual PIII700 nodes) using this architecture has shown a total reconstruction time of less than 4 min for a 720x512x512 and about 20 min for a 720x1024x1024. Further system optimizations are underway to improve these results.

## Acknowledgment

This work was supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under contract no. W-31-109-Eng-38.